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A SEVEN-JET B-47?

In this case, yes. The seventh jet, in the rear fuselage pod-mounting shown above, will be Orenda's Iroquois, designed for supersonic speeds.

The Boeing B-47 is on loan from the United States Air Force for flight testing the Iroquois in the initial subsonic phases.

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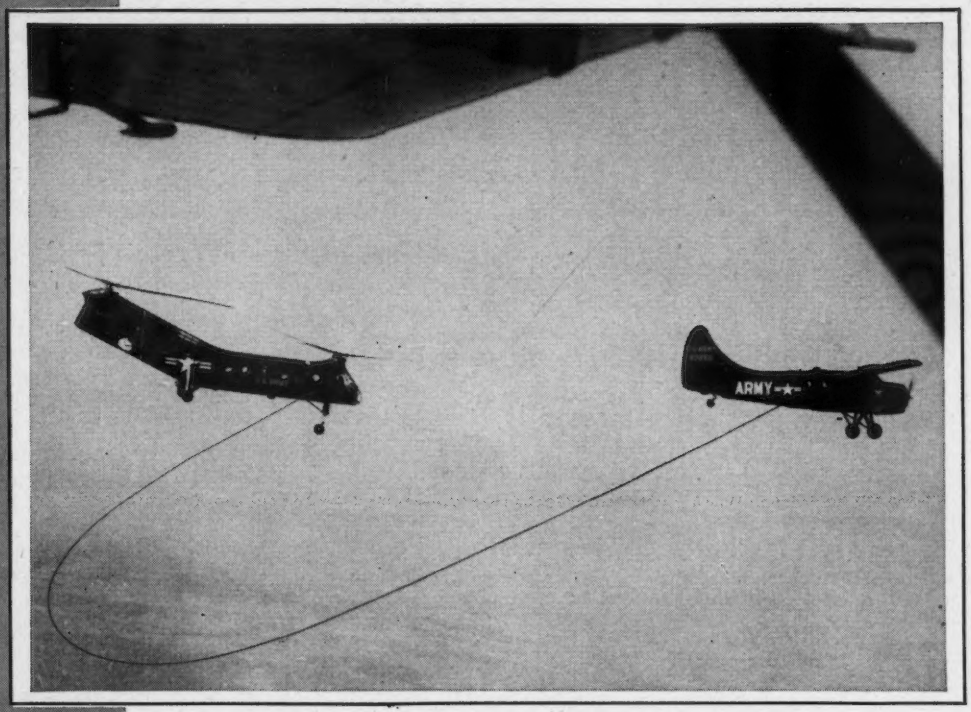

The maximum range of the Vertol H-21C light cargo helicopter is approximately 300 miles. Yet, on August 25th, 1956 an H-21C touched down at the Pentagon heliport, Washington, D.C. to complete a nearly 2700 mile non-stop flight from San Diego, California.

Army aviation officers were quick to say that the 32-hour flight proved the practicability of ferrying helicopters as much as 3000 miles to increase the striking power and mobility of ground forces.

A major assist was given to the Army's whirlybird on its transcontinental flight by a U.S. Army U-1A Otter aircraft. The Otter, converted into a flying fuel tank, refueled the H-21C in flight over Wink, Tex.; between Big Springs and Abilene, Tex.; at Maxwell AFB, Ala.; and at Fort Benning, Ga.

For the Canadian designed and built Otter, the job of wet nursing a cross-continental helicopter was just another routine chore. Many hundreds of Otters and Beavers function as prime utility support for the U.S. Army.

After refueling the helicopter, it was necessary for the Otter to land and take on fuel, and then, after dropping far behind, set out to overtake the helicopter on its non-stop trans-continental flight. Great credit is due to Captain Leonard F. Seitz, Captain James H. Stebbins, SFC Joseph Loncar and SP/3 Charles H. Glass, the crew of the U1-A tanker who carried on with little food and no rest for 30 hours continuously, as well as to the gallant crew of the H-21C.

The Otter was a logical choice to provide in-flight refueling of the H-21C. Its exceptional control qualities at slow flying speed and the high position of the tail plane combine to facilitate efficient co-ordination of the refueling maneuver. Additionally, the generous cabin space facilitates the cargoing of a maximum fuel payload.

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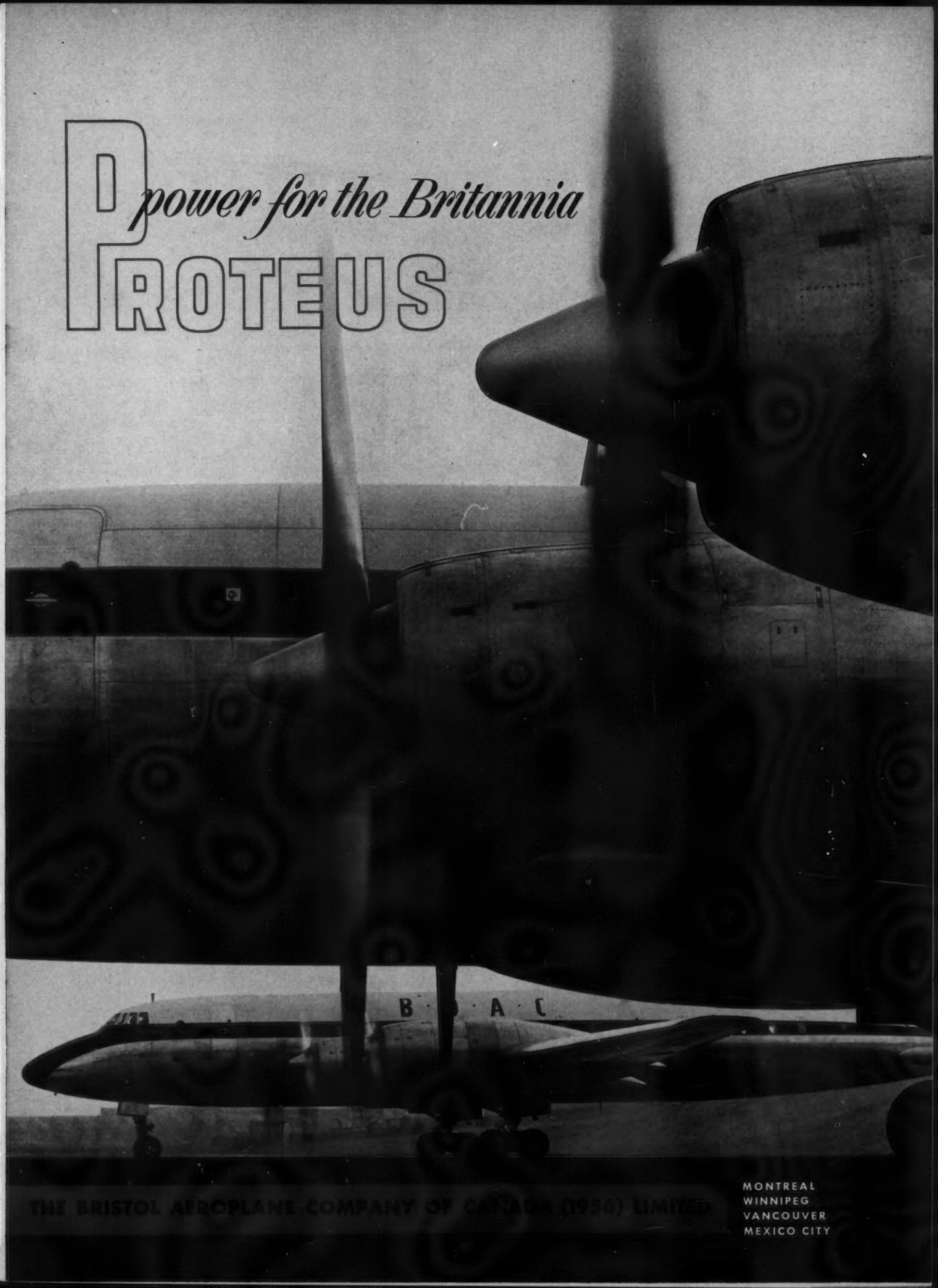
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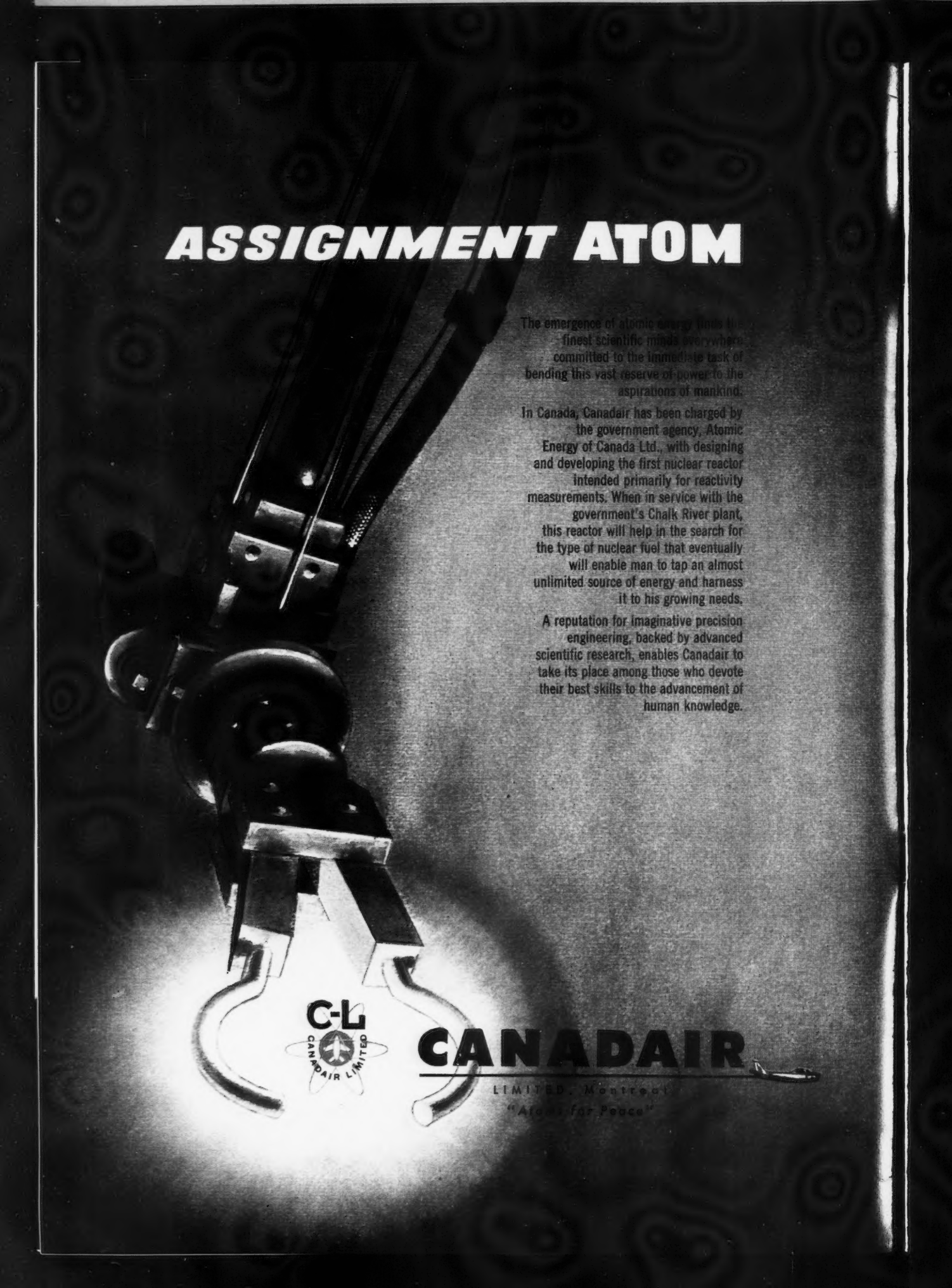
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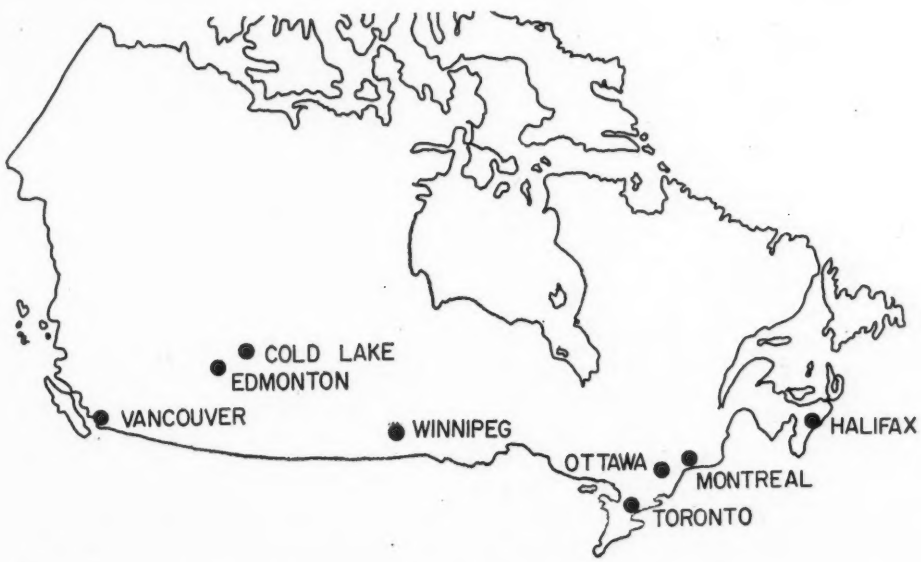
BANSHEE

The Royal Canadian Navy's Banshee F2H-3. The aircraft, built by McDonnell Aircraft Corp., is powered by two Westinghouse J34-WE34 engines.

EDITORIAL

A MARI USQUE AD MARE



THE three founder Branches of the Canadian Aeronautical Institute arose from earlier groups in Montreal, Ottawa and Toronto. When they amalgamated to form the Institute in 1954, they were chiefly concerned with setting up a workable organization between themselves, but they looked hopefully forward to the day when other centres of aeronautical activity might join them.

Nor did they have long to wait. The first native Branch was formed in Vancouver in January 1955. The firstborn always presents young parents with a host of fresh problems, and Vancouver, because of its distance from the Montreal/Ottawa/Toronto triangle, presented every problem in its most difficult form. Naturally the three original Branches had insisted on equality of representation in most of the Institute's activities, on the Council, in the Admissions Committee, in playing host to the major Institute meetings and so forth; equality of the Branches was written into every line of the constitution. Vancouver came in as an equal partner, over two thousand miles away. Certain practices had to be modified – fortunately before they had become too firmly established – but no changes in the By-laws or departures from the original principles were found to be necessary. The extremeness of Vancouver's case happily compelled the Institute to seek and adopt solutions which have generally proved adequate to meet the problems posed by subsequent and less remote Branches.

After Vancouver came Winnipeg in April 1955, Edmonton in the following November, and Cold Lake last August. And now, at the close of 1956, the formation of a Branch at Halifax has established the C.A.I. across Canada, from sea to sea.

To the pioneers in each place, who have aroused the interest of their friends and persuaded enough of them to join to meet the minimum membership requirements, the Institute acknowledges its debt of gratitude. With the formation of each Branch, the Institute has become more effective as an instrument for the dissemination and exchange of technical information; the more Branches, the more meetings and the more opportunities for association and discussion. Though the Institute has now spanned the continent, there are still gaps to be filled. Interest is stirring in Calgary, North Bay, Quebec City and elsewhere and it deserves every encouragement.

BOUNDARY-LAYER-INDUCED NOISE IN THE INTERIOR OF AIRCRAFT†

by Dr. H. S. Ribner*

Institute of Aerophysics, University of Toronto

SUMMARY

At high speeds the turbulent boundary layer washing the airplane fuselage excites skin vibration, promoting strong noise in the interior. The fluctuating exciting pressure distribution can be represented as a pattern of moving waves. A running ripple in the skin follows underneath each wave and the noise is ultimately due to these ripples. The acoustic effects of the running ripples have been determined for an infinite sheet[1]. Supersonically moving ripples radiate strong sound in the form of Mach waves; subsonically moving ripples radiate no sound.

The results are adapted to provide a tentative estimate of the noise generated at subsonic speeds in a practical fuselage. The running ripples are almost noise-free, but multiple reflections at the frames and stringers promote standing waves. An assumption is used to link the two kinds of waves and this leads to provisional calculations of noise level[1]: on this basis the noise level is predicted to vary as $\rho_e^2 U^5 \delta^3/h^3$ for thin boundary layers, changing progressively to $\rho_e^2 U^3 \delta/h$ for thick layers (ρ_e = external air density, U = speed, δ = layer thickness, h = panel thickness). Some comparisons are made with experiment. Finally, measures for noise reduction are discussed.

INTRODUCTION

It may be well to lead into the subject by way of jet noise, something you are all familiar with. Jet noise is extremely intense outside the airplane, but inside it is considerably attenuated by the fuselage. The interior noise is still uncomfortably loud in certain areas, but localized increases in insulation can reduce it to satisfactory levels. This jet noise is troublesome primarily at takeoff[2].

In cruising flight there is a serious additional source of noise: the turbulent boundary layer washing portions of the fuselage. At high subsonic speeds the boundary layer is, in fact, reported to be the major source of noise within the aircraft[3]. The noise is of such intensity as to be of serious concern in the design of contemplated transport aircraft.

The boundary-layer noise arises from skin vibration excited by the fluctuating turbulent pressure field in the layer. This pressure field, even at moderate supersonic speeds, is essentially incompressible; that is, it is localized in the layer, very little being radiated as sound. In what follows I shall refer to this turbulent pressure field as 'pseudo-sound'.

†Paper read before the Annual General Meeting of the C.A.I. in Montreal on the 4th May, 1956. This paper is essentially a condensation of UTIA Report No. 37, cited as Reference (1), plus an amplified discussion on measures of noise reduction.

*Research Associate and Assistant Professor.

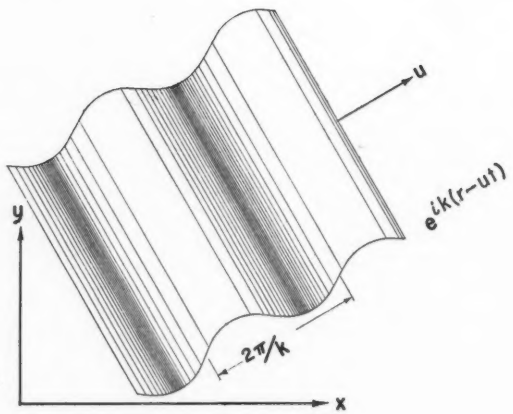


Figure 1
Moving wave of surface pressure

The root-mean-square pressure of the pseudo-sound is estimated to be of the order of the stagnation pressure of a turbulent eddy: about 0.6 of one per cent of the stream stagnation pressure[4]. This may be expressed on an acoustic scale in decibels re 0.0002 microbar. As an example, for a flight speed of 800 fps at 30,000 ft altitude the pressure level of the pseudo-sound is 132 db. This is the level an ear or a microphone immersed in the boundary layer would appear to hear. The level is so high as to produce a sensation of pain.

The fuselage skin vibration driven by this 132 db pseudo-sound will generate true sound at a lower decibel level. The question is, how much lower? It was the purpose of this investigation to attempt tentative answers to this question. A detailed analysis is given in Reference (1), and only the main physical concepts and results will be brought out in this paper.

VIBRATION OF INFINITE FLAT PANEL

Analysis of the fuselage skin vibration is complicated by the curvature and constraints imposed by the frames and stringers. Therefore, we analyze first the very much simpler substitute problem of a flat, infinite, uniform sheet.

The pseudo-sound field – that is, the random pattern of pressure with which the turbulent boundary layer bombards the skin – can be built up of simpler elements: these are waves of the type shown in Figure 1. These

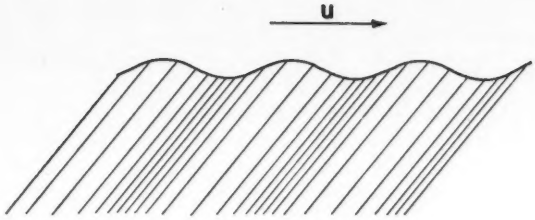


Figure 2
Generation of Mach waves by running ripples

moving waves have a wide range of wavelengths and all orientations. The speeds are a maximum in the flight direction and fall off with angle of wave yaw. The peak speeds are comparable with the flight speed.

A given pressure wave flexes the sheet into a corrugated shape much like that in the figure, and the corrugation moves along under the pressure wave. Thus we have a *running* ripple in the plate. Suppose the ripple travels at supersonic speed: then it generates Mach waves. This is illustrated by Figure 2. The Mach-wave pattern sweeping past an observer constitutes a strong sound field. Thus a supersonically moving ripple is an efficient generator of sound.

A subsonically moving ripple generates a sound field of a different character, but we will ignore the difference for the present.

These forced ripples may be compared with possible free ripples running along the plate. Free ripples may have any wavelength, but their speed depends on the wavelength (and on the plate characteristics). Suppose a forcing pressure wave happens to match a possible free-running ripple in both wavelength and speed (Figure 3). We have then a condition called coincidence; it could also be called resonance.

Figure 3
Coincidence of pressure wave and running ripple

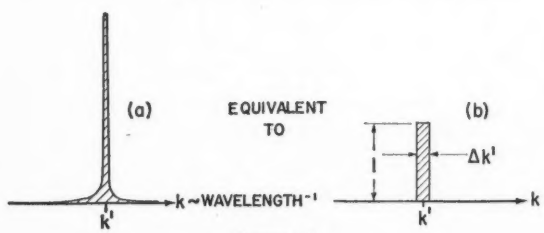


Figure 4
Panel response vs wave length

The panel response near coincidence is shown in Figure 4. The high resonant peak shows that the panel responds with large amplitude to a narrow band of pseudo-sound wavelengths and effectively ignores all others. The panel behaves essentially like a tuned filter responding only to the shaded band of wave numbers of width $\Delta k'$. (Wave number $= 2\pi/$wavelength.)

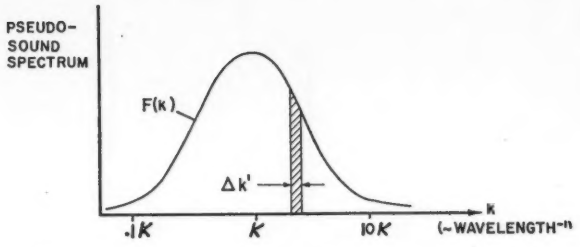


Figure 5
Panel selects narrow band from pseudo-sound spectrum

Now consider the distribution of wavelength or wave number in the boundary-layer pseudo-sound field (Figure 5): it is a bell-shaped curve. By the previous argument the panel responds only to a narrow band (shaded part) of this spectrum and ignores the rest. Different bands are selected, however, for waves of different yaw angle. When waves of all yaw angles have been taken into account, the shaded segment has swept across the entire portion of the spectrum to the left of the starting position.

The resulting integral gives the mean square ripple amplitude in the plate. The ripple amplitude depends on the relative position of the peak of the spectrum curve and the right-hand limit of the region of integration under the curve. These in turn can be related to the boundary-layer thickness δ, plate thickness h, and flight speed U.

We have in principle evaluated the mean-square ripple amplitude: now what about the noise produced? If the ripple speeds are supersonic – which means supersonic flight speeds – this is easy: we have only to calculate the ripple-produced Mach waves.

If the ripple speeds are subsonic we have, in effect, subsonic flow over a wavy wall. There are no Mach waves, but instead the flow disturbance dies out rapidly as we get away from the wall. That is, the sound field attenuates exponentially with distance from the wall. Moreover, we know that there is a complete absence of wave drag in subsonic flow. This means that no energy is carried away by sound waves. We can state, then, that subsonically travelling ripples (of unvarying amplitude) radiate zero sound energy. Actually, the pressure and particle velocity are 90° out of phase: we have a condition of "wattless" power.

APPLICATION TO BOUNDARY-LAYER NOISE IN AIRCRAFT

All this refers to the running ripples on an infinite flat plate. On an airplane fuselage, however, the running ripples strike frames and stringers and set up multiple reflections. The running ripples become lost in a pattern of standing waves. We can expect, moreover, a fair degree of randomness in phase between different portions of these standing waves. Whereas the subsonic running waves are relatively quiet, the random standing waves are efficient noise generators. In the analysis we can link the two kinds of waves together and estimate the noise generated[1].

The resulting formula has been applied to an example calculation. The calculation gives the noise pressure level

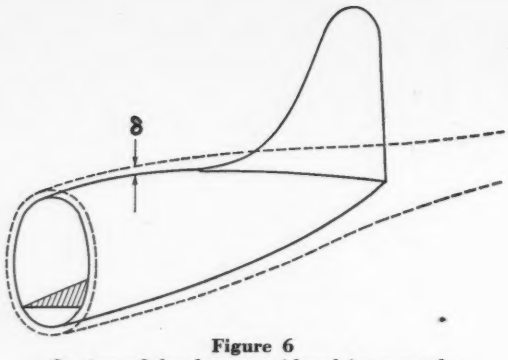


Figure 6
Section of fuselage considered in example

in the aft end of an airplane fuselage (Figure 6). The airplane may be of any size. The skin is 0.032 inch dural. To illustrate the noisiest condition the interior is taken completely bare, without acoustic insulation or even upholstered seats. In this condition the interior noise pressure is multiplied many-fold by reverberation. In our example the reverberant build-up is estimated at 14 db.

The flight altitude is taken as 18,000 ft. The interior is considered pressurized to 8,000 ft. Figure 7 shows the calculated noise curves for two flight speeds, plotted against boundary-layer thickness δ. The noise varies as δ^3 for small δ and gradually changes over to a linear variation for large δ.

This result must be noted with reservation. A recent analysis by Corcos and Liepmann[5] indicates a much more gradual (linear) variation with thickness at small thicknesses.

The difference between the two curves of Figure 7 varies progressively from 15 db to 12 db to 9 db. If the flight speed is U, this means we have a U^5 noise law at small values of δ, a U^4 law at medium values, and a U^3 law at large values. The Corcos-Liepmann analysis[5] indicates similar power laws, but their U^3 law appears to be deferred until much larger boundary-layer thicknesses.

These power laws are exhibited more clearly in Figure 8. For the 10 in boundary layer the slope corresponds to U^5 at the left end, and above 200 fps it gradually diminishes to an asymptotic U^3 law. For the 4 in layer the curve is terminated before a U^3 law is reached. One would expect to encounter thicknesses even exceeding 10 in on approaching the aft end of a large fuselage.

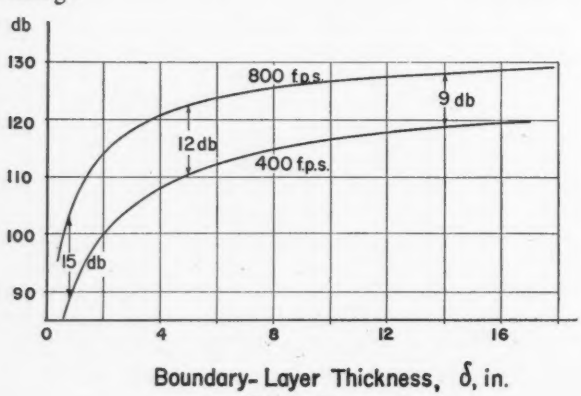


Figure 7
Calculated boundary-layer noise

Figure 9 shows some Wright Field measurements (cited in Reference (6)) of boundary-layer noise in a large glider, which follow a $U^{4.6}$ law. However, the boundary layer thickness δ is not constant, but presumably decreases slowly with increase in speed because of Reynolds number. Thus a U^5 law for constant δ would be reduced to a slightly lower power. A $U^{4.6}$ law does not seem unreasonable.

If some 7 db are added to the theoretical curves of Figure 8, to correct them to sea level air density, the 10 in and 4 in curves will bracket the experimental glider curve. This is encouraging, but it is not considered quantitative agreement because of adjustable constants in the theory.

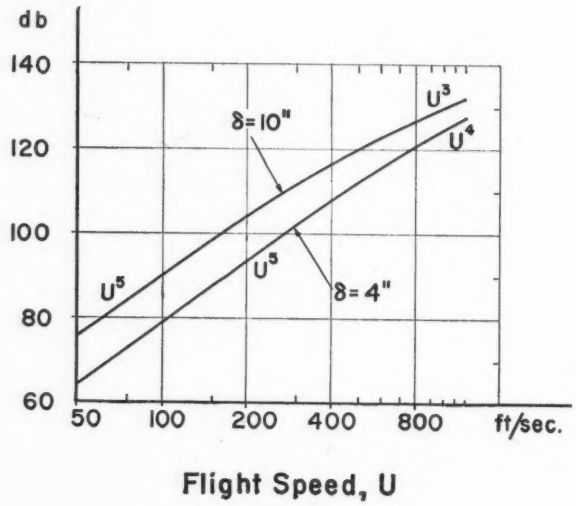


Figure 8
Calculated boundary-layer noise

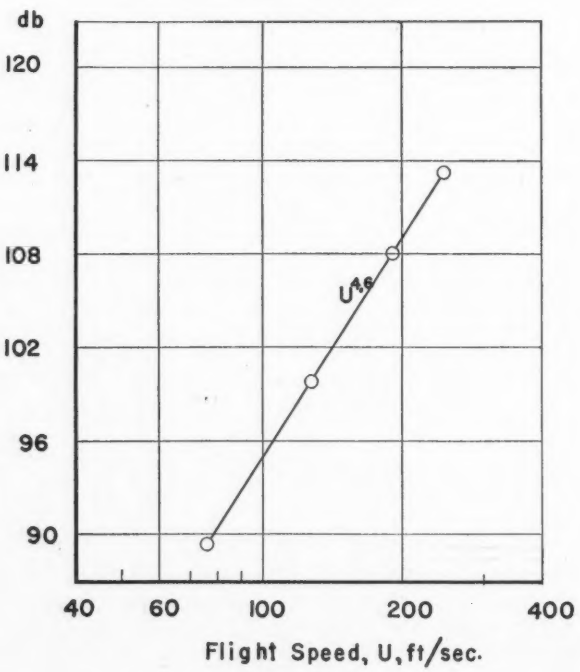


Figure 9
Measured noise in large glider

The Douglas Aircraft Company, Santa Monica Division, has been kind enough to provide recent boundary-layer noise measurements made in the aft portions of both the A-3D military and DC-7 transport airplanes. The interesting thing about the A-3D data is that it shows a U^3 law over the speed range 400 to 800 fps. The data, corrected for air density, lie close to the theoretical curve for the 10 in boundary layer. Thus we have experimental evidence for both a U^5 law and a U^3 law.

The interior of the A-3D was bare and uninsulated and probably highly reverberant, like the condition specified in the calculated example. Presumably the large glider was also. By contrast the experimental data for the DC-7 refer to an aircraft with essentially standard production insulation. I estimate the interior absorption as sufficient to eliminate all but 1 db of the 14 db reverberation build-up assumed in the example. The 4 in thick glass fibers insulation would appear to add about another 25 db attenuation, according to the acoustic law of mass. The total estimated attenuation thus comes to 13 plus 25, or 38 db.

This value may be applied to the noise level picked off the $\delta = 10$ in curve of Figure 8 at 660 fps: we have 124 db from the curve minus 38 db attenuation, or 86 db net noise level. Values very near 86 db were measured along the fuselage centerline in the DC-7 76 ft back from the noise, in a high speed dive. Against this apparent agreement we must set the uncertainties in boundary-layer thickness, panel damping and insulation attenuation.

MEASURES FOR NOISE REDUCTION

So much for estimates and comparisons with experiment. Now, what can be done to reduce the boundary-layer noise to a comfortable 70 db or less in the passenger compartment?

Firstly, we can fly higher: the noise varies as the square of density. Going from 18,000 ft to 50,000 ft decreases the noise level by 11.6 db. But further increases in altitude are uneconomic.

Secondly, we can increase either the acoustic insulation or the skin thickness. The basic insulation already provides a very considerable attenuation – for example, the value of 38 db estimated above for the DC-7 transport. However, doubling the insulation thickness adds only another 6 db attenuation, according to the acoustic law of mass. Doubling the skin thickness should behave rather similarly according to the theory[1]: it should add 3 to 9 db attenuation, depending on the boundary layer thickness. Evidently the weight penalties exceed the rewards.

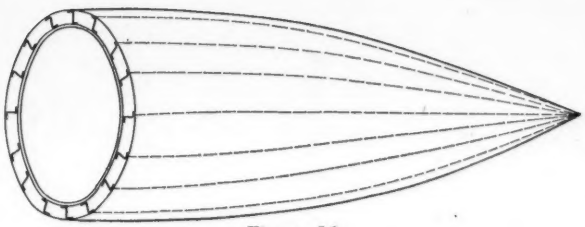


Figure 10
Proposal for noise alleviation

The addition of a second fuselage skin separated from the first by an air gap has been proposed for soundproofing[7]; this is much more efficient than increasing skin thickness for attaining high attenuation. If, moreover, the air gap is not pressurized, the air-density effect will add another 10 db attenuation at 40,000 ft.

Thirdly, we can thin the boundary layer by suction. If the (thickness)^3 law holds, this should be effective. However, the size of ducting required to thin the boundary layer appreciably would appear to be prohibitive.

Fourthly, we can increase the fuselage wall stiffness and thickness for the same weight. This implies the use of a non-metallic wall material and/or honeycomb or sandwich construction. These measures should be effective if the boundary layer is not too thick; they should then act somewhat like a thinning of the boundary layer[a].

Fifthly, we can increase the internal damping of the fuselage skin: the noise will diminish in direct proportion. Coating with a tar-like material suggests itself[8]. Also a sandwich construction, employing a viscous layer, might be effective.

Sixthly, we can try the scheme shown in Figure 10. Here we have the fuselage skin supported solely on longitudinally-running stringers. The stringers are mounted *outside* the circular frames so that the skin is not riveted to any cross-wise running members. Each panel segment has a long, uninterrupted sweep. Cross-stream skin bonds must be as light as possible.

This arrangement is intended to allow the running ripples to travel to the end of the fuselage without encountering cross-wise constraints to set up reflections and standing waves. The running ripples are finally to be absorbed without reflection by a special construction at the end. Replacement of the noisy pattern of random standing waves by the theoretically quiet running waves is expected to effect a significant reduction in noise level.

[a]These conclusions can be inferred from formulas of Reference (1). The formulas are generalized to apply to honeycomb or sandwich wall structures upon replacing E by $12EI/h^3$; in the case of sandwich structures, EI is a summation.

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CONTROL OF DEVIATING MATERIAL†

by H. G. Dickie*

Canadian Pratt & Whitney Aircraft Co., Ltd.

INTRODUCTION

WHAT do we understand by deviating material? Material, of course, refers to the product which is produced by an industry for sale and which must compete successfully with the products of other companies in the same business. When we say *deviating* material, we are referring to material which does not meet requirements. Obviously it is a small fraction of the company's product. Deviating material must be thrown away or improved so as to be as fully interchangeable and give the same service and life as the rest.

A housewife would call it a "flop" if her cake did not rise evenly, look tempting and taste delicious. She could not sell it at a bake sale. It obviously did not meet the standards which she knew had to be met if that cake was to make her the envy of all her neighbours. What she had was deviating material. She might either try to improve it by further baking or she might decide to throw it out. She will certainly attempt to bake a better one next time and, if she is prudent, she will try to discover what ruined this cake. If she takes positive steps to make sure it won't happen again, she will be controlling the deviating material.

Now just as the housewife understands what standards her product must meet, so every manufacturing industry understands what quality is required in its products. Competition eliminates a business which cannot produce a quality product or one which has to absorb the cost of producing and scrapping too much inferior non-marketable material. It is of first order importance then that a company devise an effective method of handling deviating material. It is a matter of success or failure.

Industry has to be more formal than the housewife in the definition of its product. The automotive industry has established controls suitable for mass production techniques. The aircraft industry, requiring higher quality, has had to evolve controls dictated by the functional operation of the product. The particular aircraft engine business with which I am associated has developed a satisfactory means of setting standards, inspecting its products and dealing with deviating material. You will be interested in comparing how much of this system is common to the industry and how much is unique.

†Paper read at the I.A.S./C.A.I. International Meeting in Toronto on the 27th November, 1956.

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DIVISION OF RESPONSIBILITY

Once the product has been defined by blueprints and specifications in the Production Models Engineering Department, the responsibility for producing the product is with the Works Group or, in case it is procured from a vendor, with the Purchasing Group. Both the Works Group Production Department and outside vendors must devise means for producing acceptable parts. They are primarily interested in controlling and eliminating deviating material. However the pressures of meeting production schedules and the difficulties encountered in manufacturing provide a bias which may lead to compromise of the standards set up by Engineering. Therefore it is necessary to have a completely independent department to call the signals. This is the Inspection Department, which is organized as a part of the Engineering Group to guard that the company's product is produced to a standard which does not change from one day to the next.

It is fundamental to the success of the Inspection operation that it can function independent of the pressures bearing on the Works Group. It is a prime requisite that top management permits Inspection to discharge this work in an atmosphere of indifference. This does not mean that the Inspection personnel can afford to be unsympathetic to production difficulties. On the contrary, there must be a genuine spirit of understanding and a desire to be helpful.

This paper will be concerned with the role that the Inspection Department plays in the control of deviating material, although it is to be understood that this is a function which supplements and complements the measures taken by the manufacturing people to do the same thing.

INSPECTION

The various aspects of the Inspection function are assigned to three subdivisions of the department. Quality Engineering is responsible for interpretation of drawings and specifications, for setting acceptable quality standards and for providing instructions, methods, gauges and equipment to carry out the inspection function. The Inspection Section is charged with carrying out the inspection operation on product material and determining its actual status in relation to Engineering requirements and quality standards. This is a fact finding section which

accepts parts that have been determined to meet specifications in every respect. Finally there is the Quality Review Section which is authorized to disposition and control material found to deviate from Engineering and Quality Engineering requirements. It also has the responsibility for recommending and following up the necessary corrective action to be taken by Production in order to eliminate or reduce the repetition of deviations on future parts. It is the activities of this last section which we will examine in greatest detail.

The Inspection Department must certify all parts and assemblies produced. This is done with the assistance of a sister department—the Material Control Laboratory which certifies the material from which each part is made and determines that processes such as heat treating, plating, etc., are under control and meet specifications.

QUALITY REVIEW

Classification of Manufactured Material

As the final destination of individual parts and assemblies is unknown at the time of manufacture or procurement, it is impossible to segregate material for customers. Therefore, all material in the Manufacturing Plant comes under the RCAF surveillance inspection. We shall first examine the activity of the Quality Review Section as related to parts and assemblies made in our own plant. All material which the Laboratory or Inspection finds to deviate from drawings or specifications is placed on a Quality Review Order (QRO) and split from the Production Order on which it is travelling. However in order to reduce to some extent the volume of material passing through Quality Review, Inspection Foremen are authorized to accept minor variations which are recorded in a register of Class 2 material. This register must be signed by the Quality Review Section and the RCAF to approve acceptance.

Quality Review Order

The bulk of deviating material which is placed on a Quality Review Order is sent to quarantined Quality Review cribs servicing local areas. The QRO is a six copy form which carries:

(1) The necessary information to fully identify the part or assembly.

(2) A description of the deviation, signed by the Inspector and countersigned by his Foreman or Leadman.

(3) The disposition of the material which is first signed by the Quality Review Inspector and then by the RCAF Representative.

(4) Production Foreman's signature to recognize the deviation.

(5) And, when necessary, the Production General Foreman's or Production Superintendent's signature to recognize responsibility for scrap.

The copies are distributed to Inspection, RCAF, Accounting, Production Superintendent, Production Control and the Area Dispatcher.

Responsibility of Quality Review Staff

Each crib is in the charge of a Quality Review Inspector who is an experienced inspector with a wide knowledge of machining methods and processes. He must have a good understanding of the end product, which in our case is an aircraft engine. He is required to study the deviation reported by the Inspection Section or the Production Department and must determine whether the deviation can be accepted 'as is' or if it can be corrected. In the case of correction or repair, he must specify what is to be done. If the part cannot be reworked to make it acceptable, it must be scrapped.

In-process material or parts, which are found by the Production Department to deviate in such a manner that final dimensions or specifications will be adversely affected, are referred to Quality Review for disposition. In this way any doubtful material or scrap is cleared off the floor at the earliest opportunity eliminating expensive finishing operations.

If Quality Review feels that an in-process part can be completed within limits which could be accepted, a Complete Operation decision is given. The parts are returned to Production to be completed and, if at that time they still deviate, they will again be presented to Quality Review for disposition.

As you see, the Quality Review Inspector is making decisions on acceptance or rejection of deviating material. You may well ask, how can we depend on an Inspector to carry this responsibility. It must be borne in mind that each Quality Review Inspector makes decisions in areas where he is fully familiar with the work and is confident in the knowledge of what he can accept. When there is an element of doubt, he must refer the problem to the Quality Review Investigators. The Quality Review Investigators are responsible for investigating the deviations and determining if the parts or material may be accepted. The results of the investigation are passed back to the Quality Review Inspector to form a background for future decisions.

Quality Review Investigators are trained technicians, preferably with an engineering background. They must be able to interpret specifications and be familiar with design functions. In order to assist them in arriving at a decision, they have all the company services at their disposal. Problems may be referred to the Material Control Laboratory, the Engineering Departments, Field Service etc., for advice. This advice consists of technical information pertaining to the function of each group. For instance, Field Service might be asked to discuss the wear allowances or service history of a part. The Material Control Laboratory might be asked to do a micro section on a deviating carburized part and report on its findings. This information might be passed on to Engineering with a request for a strength analysis of the deviating part.

Specialist Advice

You will notice that the word advice is used rather than decision. The disposition of the deviating material is the responsibility of the Quality Review Section. It must consider the functional advice given by other technical sections and also consider the quality standards set by the company. This leaves Engineering or any other technical section free to think in terms of the function only, when asked for advice. Of course, material considered to be unworthy by Engineering is rejected. It is obvious that a high degree of communication is necessary between sections and departments.

At this point, you may ask why Quality Review is a part of the Inspection Department rather than the Engineering Department. As we have stated, the Inspection Department is charged with certifying all material. It, therefore, follows that the section accepting deviating material must be controlled by the same Department. Also, as we have mentioned, Engineering is trained to think in terms of function and, since quality must also be considered, it is natural to place the responsibility for balancing function with quality under the supervision of the Inspection Department.

Acceptance Considerations

Quality Review acceptances are not permitted to set a precedent—they are valid for one Order only. If satisfactory corrective action is not taken on subsequent batches, Quality Review acceptance may be tightened in order to force elimination of the deviation.

Parts accepted by Quality Review must be fully interchangeable. They must give the same service and life as any other part. Since it is intended that all material must meet specifications, reworkable deviations are accepted only under exceptional circumstances, such as exist if the rework is of such a nature that there is great danger of scrapping the part, or if the machine or fixture pick up points have been lost or removed.

If a part is to be repaired, the repair must be of such a nature that the part will be fully interchangeable and must not have any loose or attaching parts which might become lost or left out at overhaul or servicing. The repair must be an integral part of the piece. For instance, if too much material were machined off a boss we would not permit the use of an extra washer at assembly. The boss would be machined down and repaired with an insert locked with a pin, to build the boss back to its correct height.

Deviations must be judged in terms of usability (which covers strength, interchangeability and wear allowances) and quality. The latter is probably the harder point on which to make a decision. Visual quality refers to the finish of the part and can best be controlled by establishing acceptable samples. Parts must have uniform machine or cutting lines with no evidence of tears and must be free of nicks, scratches, sharp edges or burrs. At times, a dimension which is still reworkable may be found to vary considerably beyond the tolerance and yet be functionally serviceable. Good quality practice requires that such parts be brought to specification.

It is impossible to establish a set of rules to determine how much over or under the basic tolerance is acceptable. The amount will vary from part to part. We must depend on a thorough knowledge of the product. Field Service findings are very useful in helping to determine that any material accepted will give the customer full and trouble free service.

Flow of Material

It is imperative that material flows smoothly and quickly through the area in order that machine set ups will not be lost. As we have pointed out, semi-finished material which deviates is split from the production batch and, if it is dispositioned for completion of operations, it must be routed back to join the original batch for balance of machining. Whenever possible, the material must be dispositioned and cleared from the cribs within forty-eight hours. This is one of the great advantages of our system. The Material Review Board procedure has been extended so that normally both Engineering and Inspection functions are handled by Quality Review. This facilitates the flow of material since it is not held up for meetings.

I should point out that if the Government Inspector on the floor does not agree with the decision of the Quality Review Inspector, the Quality Review Order is presented to his superior by a Quality Review Supervisor. If a decision cannot be reached, a formal Board Meeting consisting of Inspection, Engineering and Government representatives may be called in accordance with RCAF Quality Control Procedures.

To date, there have been few occasions when it has been necessary to resort to a Board Meeting. In fact, we have found that if one is called it is usually for the purpose of recording and ensuring that corrective action is underway, rather than to reach agreement on the disposition of the part.

Vendor Material

The Quality Review procedure for handling vendor material must be modified to some degree. This is primarily due to the following factors. It is more difficult to exercise the same influence on a vendor as can be applied on the company. The distance between the vendor's plant and the company introduces communication and flow time factors. For example, if material is returned for correction, can schedules be met? This is extremely important on American parts, which must pass through Customs to and from the company. Purchased material, which is found by Inspection to deviate from specification, is placed on a Purchased Quality Review Order and sent to the Quality Review crib for dispositioning. The parts are reviewed by the Quality Review Inspector and accepted or rejected in the same manner as parts made in our plant. Any parts or material which must be rejected are turned over to the Vendor Quality Section of the Purchasing Department, which has the responsibility for procuring acceptable material.

If the parts cannot be salvaged, they are returned to the vendor to be scrapped. If they are reworkable, Vendor Quality must balance the time element to decide whether the parts should be returned to the vendor for rework or be reworked in our own plant at the vendor's expense. The vendor's approval is obtained for work which may be necessary.

Another problem arises where purchased parts are inspected on the basis of a sampling plan. If the sample rejects the batch, the parts are normally returned to the vendor for segregation. Here again the time element may decree that, in order to meet schedules, Purchasing must arrange for 100% inspection at our plant. We feel that these costs are vendor responsibilities and should be borne by him.

When a vendor finds that material is deviating, we require that he declare it on an "Authorization to Ship Deviating Material" form. This form is completed by the vendor, describing in detail the deviation and the corrective action taken, and forwarded to Quality

Review for consideration. If the shipment is approved by both Quality Review and the RCAF, the material must be clearly identified and sent in for review and final decision. This helps to eliminate unnecessary handling of deviating material and makes the vendor management more conscious of outgoing quality level.

PRODUCTION

Information derived from Quality Review Orders is used to provide facts for Production, in order that it may take steps to prevent recurrence of deviations. Furthermore, the Quality Review Order is designed so that Production is immediately made aware of any deviations found on parts inspected. Before the Quality Review Inspector dispositions any Quality Review Order, he must ensure that the Production area foreman has signed the Order recognizing the deviations found. The foremen are, therefore, immediately aware of the deviations produced and can check back to determine the cause and take the necessary corrective action.

If, when the Quality Review Order is dispositioned, the parts are found to be scrap, the Superintendent or General Foreman of the area producing the parts is required to sign the Order recognizing the responsibility for the scrap. In such cases, he will immediately check back with his Foreman to determine the cause and to see that proper action has been taken.

When material is scrapped, the cause of the scrap is coded on the Quality Review Orders, for example, operator's error, set-up, machine failure, handling damage, incorrect tools, processing errors etc. A report called "Material Lost in Process" is distributed to those concerned showing the cause of scrap.

Quality Review Meetings

In addition, Quality Review Meetings are held at regular intervals to discuss problems relating to deviating material. This is a Production meeting held with the assistance of the Quality Review Section. Representatives from all phases of production are in attendance and usually include the Works Manager, Production Engineer, Process Planner, Engineering Representative, Production Superintendent, General Foreman and Foreman. The Production Department prepares the agenda for the meeting from recurring deviation reports and problems which it is unable to overcome. In many cases the cause of a deviation may be corrected before the parts reach Inspection. These meetings are successful because problems are marked for action and supervision is present at such a level to ensure that the necessary action is taken. No problem may be dropped from the minutes of the meeting until a solution satisfactory to all concerned has been reached. The minutes are published and circulated to all concerned, including the Group Managers.

Production Liaison

Quality Review personnel assist Production with a continual assessment of the quality of the parts being produced. Whenever any one phase appears to be in trouble, it is immediately brought to the attention of Production supervision.

There are instances when Production may feel that it is impossible using given processes to produce a part within the close tolerances called for by the drawing. We encountered this problem on the first crankshafts produced in our plant. Additional machining operations were requested by Production which apparently would extend the schedules and increase the cost. This problem was brought to the Quality Review Meetings and within the space of a few months difficulties had been resolved and Inspection was accepting crankshafts without Quality Review action. Instead of schedules being revised, it was found that they were now being met with comparative ease.

Vendor Liaison

As I have pointed out, all rejected purchased material is turned over to Vendor Quality Section of Purchasing for final disposition and corrective action. This group, using Quality Review records, keeps a rating sheet on each vendor. This rating sheet shows a month to month quality history of all parts or materials inspected, the percentage accepted by Inspection, the percentage accepted and the percentage rejected by Quality Review. These sheets are forwarded to vendors with suitable comments on the rating. The Vendor Quality rating sheets are used by the Purchasing buyers as an aid in placing future orders. In addition, the Vendor Quality Section has quality advisors who visit vendors regularly to assist them in any problems which they may have with our work.

CONCLUSION

The Quality Review system which has been outlined has been fully accepted by the RCAF and forms part of the Inspection system approved by the Department of Transport. Its obvious advantages are:

(1) Deviating material is isolated and controlled.
(2) Material is moved rapidly avoiding costly delays.
(3) Quality is kept at a uniform level.
(4) Every possible effort is made to ensure corrective action.
(5) Responsibility for clearing deviating material lies under the control of one department.

The approach taken is that quality cannot be inspected into a product—it must be built in. Therefore, the system does not merely toss out the imperfect but provides a continuous liaison with the Production Departments and the vendor in order to generate the feeling for quality which the product demands.

SOME PERFORMANCE PROBLEMS ASSOCIATED WITH THE MACH 2 FIGHTER†

by J. Morris*

Avro Aircraft Limited

SUMMARY

This paper considers the choice of configuration for a fighter aircraft designed for a combat speed of $M = 2.0$ from the viewpoint of performance efficiency. Particular attention is given to the influence of drag due to lift and trim drag on the choice of wing planform and type of longitudinal control.

INTRODUCTION

LOOKING beyond the next generation of fighter aircraft, it is obvious that requirements will exist in the reasonable future for fighters having operational combat speeds of $M = 2.0$ and above. The object of this paper is to show how performance requirements might influence the shape of the aircraft designed for cruise and combat at $M = 2.0$. In making the analysis, no account has been taken of the variations in weight implicit in the different configurations considered. A generalized approach to weight variation is difficult as specific requirements for a given aircraft usually dominate.

For the purpose of this paper, it is assumed that the aircraft will have combat altitude of 60,000 feet and a 2 g level turn capability at combat speed. It is also assumed that it will be capable of landing and taking-off conventionally and this restriction limits the wing leading edge sweep to about 65° and aspect ratios to greater than 1.5.

Fighter aircraft are usually designed to a specification issued by the appropriate government body which lays down minimum requirements on range, maximum level speed, ceiling and thrust limited turn capability at a fixed speed and altitude. In the old days there was usually a conflict between the top speed and ceiling requirements because the optimum wing loading to satisfy the top speed requirement was much higher than that for ceiling — the designer had, therefore, to compromise. The situation is different today because top speeds are limited by thermal rather than thrust/drag considerations, so that it is possible to optimize the aircraft at the ceiling or for manoeuvrability, whichever is the more critical.

If the ceiling requirement is more difficult than that for manoeuvrability, it obviously pays to choose the wing loading to give maximum lift/drag ratio at the ceiling. If the manoeuvrability requirement is the more difficult, then range will influence whether the lift/drag ratio be maximized for level flight at the specified manoeuvring load factor in the turn or at some intermediate load factor. Under these conditions drag due to lift is very important. For example, if an aircraft with a flat wing (i.e. no camber or twist), designed for a 2 g level turn, has the lift/drag ratio maximized in level flight then the drag due to lift at 2 g is four times the zero lift drag, but if the lift/drag ratio is maximized at 2 g then the lift drag is equal to that at zero lift.

It will be shown that trim drag can also be very important and that for the Mach 2 fighter drag due to lift is more important than zero lift drag and serious consideration must be given to minimizing trim drag.

LIST OF SYMBOLS

L	lift
D	drag
N	normal force
L_T	lift on tailplane
D_T	drag of tailplane
N_T	normal force on tailplane
C_D	D/qS
C_L	L/qS
C_N	N/qS
C_M	$M/qS\bar{c}$
C_{D_T}	D_T/qS_T
C_{L_T}	L_T/qS_T
C_{N_T}	N_T/qS_T
C_T	thrust coefficient T/qS
C_{D_t}	trim drag coefficient
C_{L_w}	lift coefficient of aircraft less tail
C_{D_o}	zero lift drag coefficient
$C_{D_{oT}}$	increment in a/c zero lift drag in terms of the tail area
$C_{M\delta}$	$C_{M_o} + (h - h_o)\, C_L$
C_{M_o}	pitching moment at zero lift for aircraft less tail
ΔC_{D_c}	drag coefficient of control
ΔC_{L_c}	lift on control/qS
ΔC_{L_w}	lift on complete aircraft due to control deflection

†Paper read at the Annual General Meeting of the C.A.I. in Montreal on the 4th May, 1956.

*Assistant Chief Aerodynamicist.

K_2	$\frac{\Delta C_{L_c}}{\Delta C_{L_w}}$
K_w	lift drag-rise factor
K_{eff}	effective lift drag-rise factor
a_1	$\frac{\partial C_L}{\partial \alpha}$
a_2	$\frac{\partial C_L}{\partial \delta}$
a	$\frac{\partial C_L \text{ less tail}}{\partial \alpha}$
a_T	$\frac{\partial C_{L_T}}{\partial \alpha_T}$
$h\bar{c}$	centre of gravity location
h_o	aerodynamic centre
h_δ	centre of elevator lift
S_t	area of control
S_T	area of tail
S	area of wing
A	wing aspect ratio
$\bar{c}$	wing aerodynamic mean chord
l_T	distance from half-chord point of tail to c.g. of aircraft
l_o	distance from half-chord point of tail to h_o
M	Mach number
W	weight of aircraft
p	ambient pressure
n	load factor
e	induced drag factor
α	wing incidence
α_T	incidence of tail relative to wing chord
ε	angle of downwash relative to wing chord
γ	ratio of specific heats
δ	control angle
q	$\rho V^2/2$

TRIM DRAG

To have positive longitudinal static stability, the centre of gravity of the aircraft must be in front of the aerodynamic centre, which means that for trimmed flight the controls must be deflected to re-distribute the air loads so that the centre of lift passes through the centre of gravity and brings the aircraft into balance. This re-distribution of load, which takes place primarily on the controls, also changes the drag and the difference in drag between controls deflected and undeflected at a given lift coefficient is called the trim drag. Methods for calculating the trim drag at supersonic speeds for tailless and tailed configurations are given in the Appendix to this paper.

The drag coefficient of an aircraft with a flat wing can be expressed as:

$$C_D = C_{D_o} + K_w C_L^2 + C_{D_t}$$

For configurations of practical interest the trim drag coefficient for a tailless aircraft is given at Mach number greater than about 1.9 by the following approximate formula:

$$C_{D_t} = \frac{1}{dC_L/d\delta}\left(\frac{h-h_o}{h_o-h_\delta}\right)^2 C_L^2$$

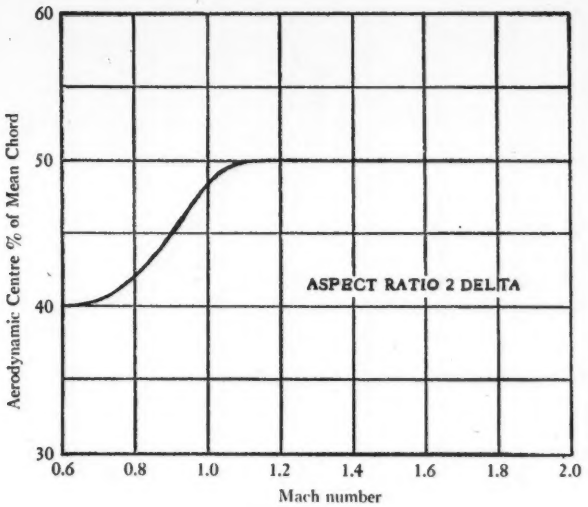


Figure 1

These two equations can be combined to give

$$C_D = C_{D_o} + K_{eff}\, C_L^2$$

where

$$K_{eff} = K_w + \frac{1}{dC_L/d\delta}\left(\frac{h-h_o}{h_o-h_\delta}\right)^2$$

The trend in tailless aircraft for operation at supersonic speeds seems to be towards the delta planform with aspect ratio of about 2 and the effect of trim drag on the effective lift drag-rise factor K_{eff} will be illustrated by taking this planform as an example.

A typical variation of aerodynamic centre (h_o) with Mach number for an aspect ratio 2 delta is shown in Figure 1, and it will be noted that at supersonic speeds it is located at 50% of the mean chord. The location of the centre of elevator lift (h_δ) will, at supersonic speeds, be close to the centre of area of the control – for practical configurations it will be around 90-95% of the mean chord. The following formula gives a reasonable approximation to the elevator lift slope at supersonic speeds:

$$\frac{dC_L}{d\delta} = \frac{3.5}{\sqrt{M^2-1}}\frac{S_t}{S}$$

The effective lift drag-rise factor for a tailless aircraft with an aspect ratio 2 delta wing can then be expressed (for $M > 1.9$) as:

$$K_{eff} = K_w + 1.4\sqrt{M^2-1}\,(S/S_t)\,(h-0.5)^2$$

The two main parameters that influence trim drag at supersonic speeds are then, control area ratio and the location of the centre of gravity, which is what one would expect. Some examples which illustrate the effect of centre of gravity location and S_t/S on K_{eff} are shown in Figure 2. Also shown in this figure are typical values for a canard and an aircraft with a rear tail. We see that if the centre of gravity is located at 34% of the mean chord, to give a static margin of 6% at subsonic speeds, then the effective induced drag (i.e. drag due to lift plus trim drag) at $M = 2$ will be more than doubled with the part span control. Increasing the span of the control

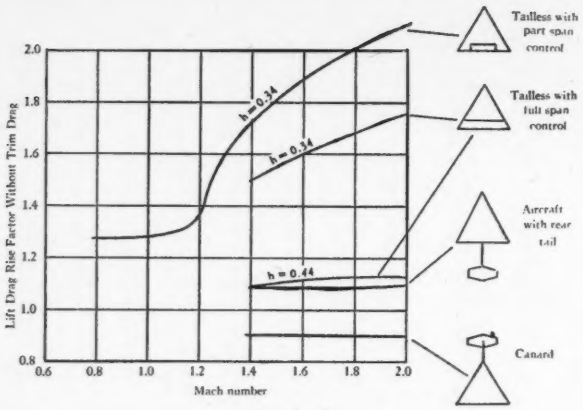


Figure 2

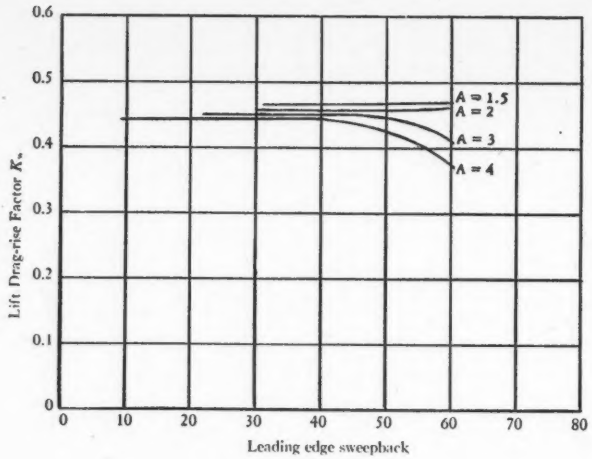


Figure 3

with the same centre of gravity position produces appreciable gains.

However, the reason for the high trim drag of the tailless aircraft in supersonic flight is the large increase in static margin resulting from the aft movement of the aerodynamic centre. The obvious way to eliminate the problem is to move back the centre of gravity of the aircraft to maintain the same static margin as in subsonic flight. Since the proportion of total weight carried in the form of fuel will be high, it is possible to control this centre of gravity position by appropriate transfer of fuel. There are, of course, the practical problems associated with an installation of this type but, in view of the very high incentive, there is no doubt that these can be overcome and Figure 2 shows how the tailless aircraft with the controllable centre of gravity is comparable to the aircraft with a rear tail on the basis of trim drag. The effective lift drag-rise factor of the canard is appreciably less than that of either of the two other configurations considered and is, in fact, less than the lift drag-rise factor of the untrimmed aircraft wing, as in this case the trimming load is acting upwards and effectively reducing the load to be carried by the wing.

Although outside the particular scope of this paper, it may well be asked why, in view of the foregoing, the delta planform has proved to be so popular for the present generation of supersonic fighters. Here again it is necessary to point out that trim drag is only one parameter in determining performance efficiency and performance efficiency is only one aspect of the problem of designing an effective fighter aircraft. Practical considerations and weight variations can more than offset a result determined by consideration of performance efficiency alone.

DRAG DUE TO LIFT

Experiments show that the lift drag-rise factor for flat wings with supersonic leading edges is given to a close enough approximation for the purposes of this paper by the reciprocal of the lift slope, i.e. $K_w = d\alpha/dC_L$

A comparison of experimental values of the lift slope and these calculated by theory show good agreement.

At a Mach number of 2, the Mach cone is swept back at 60° to the normal to the flight path; we can, therefore, estimate the lift drag-rise factor, using the theoretical lift slopes, for wings with leading edge sweep up to at least 60°.

The lift drag-rise factor has been estimated over a range of aspect ratios from 1.5 to 4.0 and leading edge sweep up to 60° and is shown plotted in Figure 3. The effect of taper ratio was found to be small and the curves in the figure can be taken as applying to taper ratios from zero to about one half. The lift drag-rise factor is almost constant over a wide range of sweep and aspect ratio; small gains might be achieved with wings of high aspect ratio and sweep but the very large wing weight penalties associated with the type of planform would discourage their use.

It would appear then that for flat wings the choice of wing planform will be dictated by considerations other than those of drag due to lift.

ZERO LIFT DRAG

It is difficult to generalize about the effect of wing planform on the zero lift drag at a Mach number of 2. We know from experiments on isolated wings that the zero lift drags do not agree very well with theory, particularly when the wing leading and trailing edges are near sonic. The wave drag of wing-body combinations can be calculated by methods such as the supersonic area rule but, to the author's knowledge, no comparison has been made between theory and experiment that would enable us to assess their accuracy at $M = 2$. We will content ourselves therefore with the following general observations, based on a survey of experimental data on wing-body combinations.

(1) The effect of sweepback for a given aspect and taper ratio is small; unswept wings having slightly less drag than the swept.
(2) Taper ratio between 0-0.25 has no appreciable effect.
(3) Increasing aspect ratio produces significant increase in drag.

It will be noted that the three conditions for minimum wing structure weight, i.e. small sweepback, taper and aspect ratio satisfy the conditions for minimum zero lift drag coefficient.

Aircraft with small sweepback must have a tail for stability reasons and this will increase the minimum drag coefficient. The tailless aircraft incurs a drag penalty

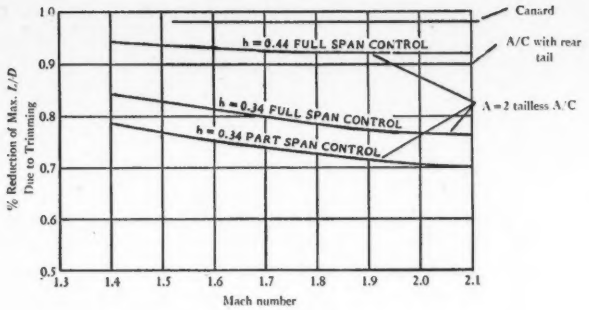

Canard
A/C with rear tail
h = 0.44 FULL SPAN CONTROL
h = 0.34 FULL SPAN CONTROL
h = 0.34 PART SPAN CONTROL
A = 2 tailless A/C
% Reduction of Max. L/D Due to Trimming
Mach number

Figure 4

due to the sweepback necessary for stability. A comparison made by the author of a tailless and a tailed configuration with wings of the same aspect and taper ratio showed that the tailless aircraft had a zero lift drag coefficient that was 5% lower than that with a tail.

Comparison of Lift/drag Ratios

Since we are considering the different configurations from the viewpoint of performance efficiency, the maximum lift/drag ratio has been selected as the appropriate index by which to make the comparison. Figure 4 shows the comparison for the three configurations selected, namely, canard, tail aft and tailless. In the case of the configurations with tails, the half chord sweep of the wing is zero and the tailless configuration has the delta planform. All have aspect ratios 2 wings with zero taper ratio.

The lift/drag ratio of the canard is about 6% better at a Mach number of 2 than the tailless with the centre of gravity located at 44% of the chord, and 8% better than the tail aft configuration. If the centre of gravity of the tailless configuration is not moved back at supersonic speeds, its lift/drag ratio will be appreciably lower than those with a tail.

It is interesting to note that, from the viewpoint of performance efficiency, the configurations considered lie within an 8% spread.

WING LOADING

It is obvious that, to minimize thrust and fuel consumption, the lift coefficient for maximum lift/drag ratio should be made to occur between 1 g and the specified load factor at combat speed and altitude. It can easily be shown that in this case the wing loading is given by the following expression:

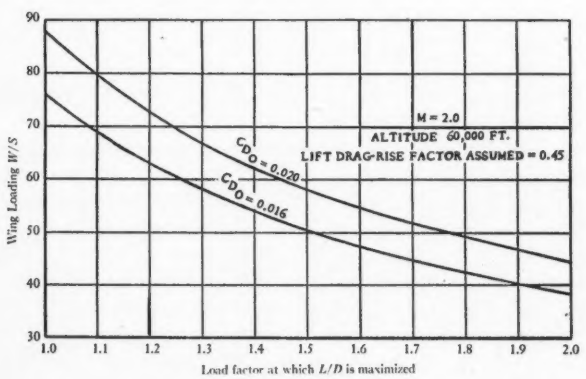

M = 2.0
ALTITUDE 60,000 FT.
LIFT DRAG-RISE FACTOR ASSUMED = 0.45
C_{D_0} = 0.020
C_{D_0} = 0.016
Wing Loading W/S
Load factor at which L/D is maximized

Figure 5

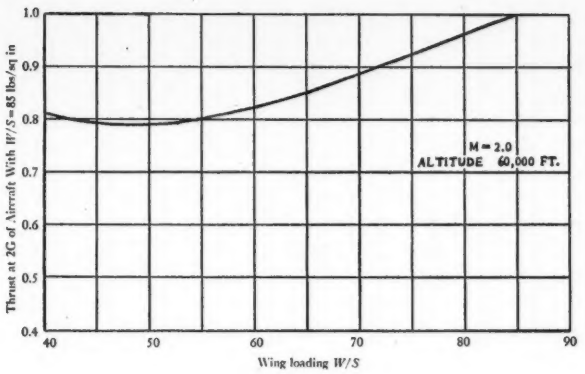


Figure 6

$$\frac{W}{S} = \left(\frac{C_{D_0}}{K_{eff}}\right)^{\frac{1}{2}} \frac{\gamma p M^2}{2 n_M}$$

where n_M is the load factor at which the lift/drag ratio is maximized and p is the ambient pressure. The variation of W/S with n_M for $M = 2$ at 60,000 ft is given in Figure 5; the values of the zero lift drag coefficient cover the likely range. The optimum wing loading should then be between 35-90 lb/sq ft.

The effect of wing loading on thrust required at 2 g is shown in Figure 6, where the thrust required at a given wing loading, divided by the thrust required for a wing loading of 85 lb/sq ft, is given as a function of wing loading. When compiling the data for Figure 6, it was assumed that the fuselage shape and size remained fixed whilst the wing area was varied and allowances were made for variations in wing, fuel and engine weight. It was also assumed that the wing planform had zero half chord sweep, aspect ratio 2, zero taper ratio and 3% thickness chord ratio, but it is believed that a different planform would not produce significantly different results. We see that minimum thrust occurs at wing loadings between 40-55 lb/sq ft.

In considering the effect of range on optimum wing loading, it has been necessary to select suitable values. Since we are discussing a very advanced aircraft with a cruising speed of Mach = 2, it may well be that mission radii will be short and values of 100 and 200 nautical miles have been selected. The fuel required for these missions is shown as a function of wing loading in Figure 7. The variation of fuel required with wing loading is not large

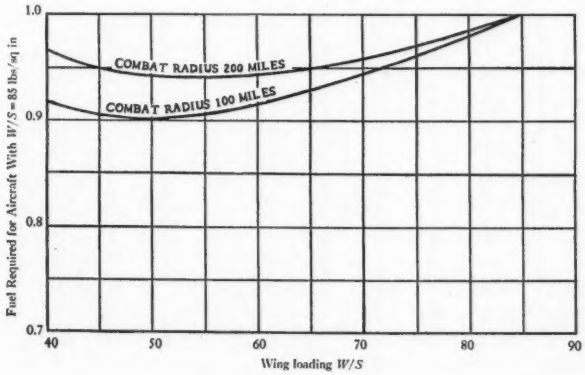


Figure 7

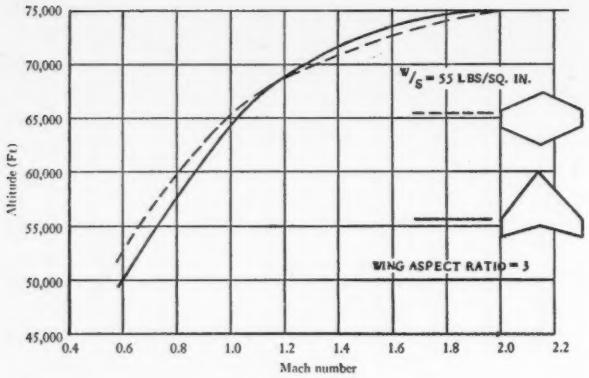


Figure 8

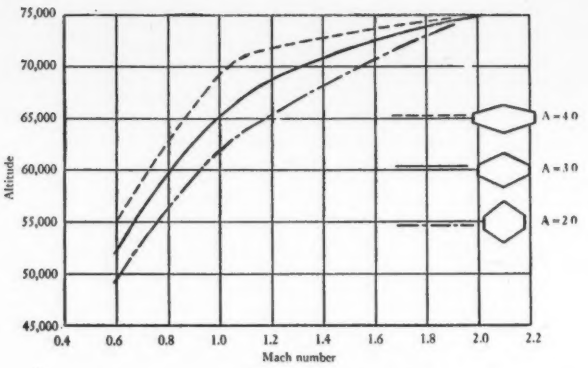


Figure 9

and a minimum occurs at a wing loading of approximately 50 lb/sq ft.

The landing problem has some influence on the possible range of wing loading for different configurations. The maximum wing loading for the low aspect ratio tailless is not likely to exceed 45 lb/sq ft due to limitations on ground angle. The tail aft aircraft will, if flaps are used, have acceptable landing speeds and ground angles at wing loadings up to 90 lb/sq ft and the canard could achieve similar loadings.

PERFORMANCE AT MACH NUMBERS LESS THAN 2

Up to this point we have concentrated on optimizing the aircraft at a Mach number of 2, but performance at off-design conditions might influence the choice of wing planform. The parameter that has been chosen to illustrate the effect of wing planform at off-design Mach numbers is ceiling, as this is most important to a high altitude fighter.

It is generally believed that aircraft with swept wings have superior performance to those with unswept wings at transonic speeds. A comparison was, therefore, made between an aircraft with an unswept wing and one swept at 40° (half chord sweep), both of aspect ratio 3, and the difference in ceiling at any Mach number below 2 was found to be small (see Figure 8). The reason for this is that the aircraft with the lowest value of $\sqrt{K_{eff}/(C_T - C_{D_o})}$ at a given Mach number will have the highest ceiling and, at transonic speeds, the thrust coefficient of the Mach 2 aircraft will be about six times as large as the zero lift drag coefficient. A 25% increase in C_{D_o} changes the ceiling parameter $\sqrt{K_{eff}/(C_T - C_{D_o})}$ by only 2.5%; a 25% increase of K_{eff} would change it by 11.5%.

The above example shows that the lift drag-rise factor is much more important than the zero lift drag coefficient in its effect on high altitude performance at off-design Mach numbers. We know that at subsonic speeds the lift drag-rise factor can be reduced by increasing aspect ratio and a comparison has been made of the performance of aircraft with unswept wings of aspect ratio 2, 3 and 4 (see Figure 9). Increasing the aspect ratio from 2 to 4 increases the ceiling by 6,500 ft at a Mach number of 1. The thrust and weight penalties associated with increasing aspect ratio are large; the aircraft with the aspect ratio 4 wing would require about 20% more thrust and would be about 15% heavier than that with the aspect ratio 2 wing. If the thrust of the aspect ratio 2 aircraft were increased by 20%, the ceiling would be increased by 2,500 ft at $M = 2$ and its transonic and subsonic performance would be roughly equal to that with aspect ratio 3.

CONCLUSIONS

This investigation has shown that, from the viewpoint of performance and efficiency, there is little to choose between the canard, tail aft and tailless configurations for an aircraft with 2 g level turn capability at $M = 2$ at 60,000 ft. The highest efficiency is found in a canard with a wing loading of 55 lb/sq ft. It would have an unswept wing with low aspect ratio probably limited by landing considerations to above 1.5. The tail aft aircraft would be some 8% less efficient than the canard; and the tailless aircraft, provided it has provision for moving the centre of gravity in flight, would be 6% less efficient than the canard.

From this is may be concluded that other considerations resulting from the particular aircraft specification will almost certainly determine the configuration to be selected.

APPENDIX

APPROXIMATE METHODS FOR ESTIMATING TRIM DRAG

Tailless Aircraft

It can easily be shown that the theoretical drag of a two dimensional airfoil at supersonic speeds can be expressed as

$$C_D = C_{D_o} + \frac{\partial C_D}{\partial \alpha^2}\alpha^2 + \frac{\partial C_D}{\partial(\delta+\alpha)^2}\delta^2 + \frac{\partial C_D}{\partial(\delta+\alpha)^2}2\,\delta\alpha \qquad (1)$$

and the equation will have the same form in the three dimensional case.

The drag of the control surface of a two dimensional wing in an inviscid flow is equal to the component of the normal force on the control in the flight direction i.e.

$$\Delta C_{D_c} = \Delta C_{L_c}(\delta + \alpha)\cos\theta$$

and

$$\Delta C_{D_c} = \frac{\partial C_L}{\partial \delta}(\delta+\alpha)^2\cos\theta$$

therefore

$$\frac{\partial C_D}{\partial(\delta+\alpha)^2} = \frac{\partial C_L}{\partial \delta}\cos\theta$$

In the three dimensional case

$$\Delta C_{D_c} = \frac{\Delta C_{L_c}}{\Delta C_{L_w}} \Delta C_{L_w} (\delta + \alpha) \cos\theta$$

where ΔC_{L_c} is the lift coefficient of the load on the control and ΔC_{L_w} is the lift coefficient of the load on the control plus any load induced on the wing by control deflection.

$$\frac{\partial C_D}{\partial(\delta+\alpha)^2} = K_2 \frac{\partial C_L}{\partial \delta} \cos\theta \qquad (2)$$

where $$K_2 = \frac{\Delta C_{L_w}}{\Delta C_{L_c}}$$

and K_2 can be estimated by linearized wing theory.

It is sometimes convenient to re-arrange Eq. (1) by substituting for $\frac{\partial C_D}{\partial(\delta+\alpha)^2}$ from Eq. (2) and for α from the lift equation

$$C_L = a_1\alpha + a_2\delta$$

We then have

$$C_D = C_{D_o} + \frac{C_L^2}{e\pi A} + \left(\frac{K_2}{a_2} + \frac{1}{e\pi A} - \frac{2K_2}{a_1}\right)(a_2\delta) + \left(\frac{K_2}{a_1} - \frac{1}{e\pi A}\right) 2C_L a_2 \delta \qquad (3)$$

The first two terms in the above equation represent the zero lift drag coefficient and the conventional induced drag and what remains we define as the trimming drag coefficient C_{D_t}.

The pitching moment due to the controls at constant lift coefficient is $(h_o - h_\delta)\ a_2\delta = C_M{}^\delta$ and substituting for $a_2\delta$ in Eq. (3) gives

$$C_{D_t} = \left(\frac{K_2}{a_2} - \frac{2K_2}{a_1} + \frac{1}{e\pi A}\right)\left(\frac{C_M{}^\delta}{h_o - h_\delta}\right)^2 + \left(\frac{K_2}{a_1} - \frac{1}{e\pi A}\right)\frac{C_M{}^\delta\, 2C_L}{(h_o - h_\delta)} \qquad (4)$$

and in trimmed flight $C_M{}^\delta = C_{M_o} + (h - h_o)C_L$

if $C_{M_o} = 0$ Eq. (4) becomes

$$C_{D_t} = \left(\frac{K_2}{a_2} - \frac{2K_2}{a_1} + \frac{1}{e\pi A}\right)\left(\frac{h-h_o}{h_o-h_\delta}\right)^2 C_L{}^2 + \left(\frac{K_2}{a_1} - \frac{1}{e\pi A}\right)\left(\frac{h-h_o}{h_o-h_\delta}\right) 2C_L{}^2 \qquad (5)$$

At Mach numbers greater than about 1.9

$$C_{D_t} \approx \frac{K_2}{a_2}\left(\frac{h-h_o}{h_o-h_\delta}\right)^2 C_L{}^2$$

Tail Aft Aircraft

The aerodynamic incidence of the tail $= \alpha + \alpha_T - \delta$ and its incidence relative to the flight path $= \alpha + \alpha_T$

If we assume the resultant force on the tail is normal to the chord and that $C_{N_T} \approx C_{L_T}$ the drag coefficient of the tail is

$$C_{D_T} = C_{D_{oT}} + C_{L_T}(\alpha + \alpha_T) \qquad (6)$$

The tail lift coefficient can be expressed as

$$C_{L_T} = a_T(\alpha + \alpha_T - \epsilon)$$

and substituting for $\alpha + \alpha_T$ in Eq. (6) we get

$$C_{D_T} = C_{D_{oT}} + C_{L_T}\left(\frac{C_{L_T}}{a_T} + \epsilon\right) = C_{D_{oT}} + C_{L_T}\left(\frac{C_{L_T}}{a_T} + \frac{d\epsilon}{d\alpha}\alpha\right) \qquad (7)$$

The lift coefficient of the aircraft less tail $C_{L_w} = a\,\alpha$ and substituting for α in Eq. (7) gives

$$C_{D_T} = C_{D_{oT}} + C_{L_T}\left(\frac{C_{L_T}}{a_T} + \frac{d\epsilon}{d\alpha}\frac{C_{L_w}}{a}\right)$$

The drag coefficient of the aircraft less tail

$$C_D = C_{D_o} + K_w C_{L_w}{}^2$$

and the drag coefficient of the complete aircraft is then

$$C_D = C_{D_o} + C_{D_{oT}}\frac{S_T}{S} + K_w C_{L_w}{}^2 + C_{L_T}\left(\frac{C_{L_T}}{a_T} + \frac{d\epsilon}{d\alpha}\frac{C_{L_w}}{a}\right)\frac{S_T}{S} \qquad (8)$$

The lift coefficient of the complete aircraft

$$C_L = C_{L_w} + C_{L_T}\frac{S_T}{S} \qquad (9)$$

and substituting for C_{L_w} in Eq. (8) and re-arranging gives

$$C_D = C_{D_o} + C_{D_{oT}}\frac{S_T}{S} + K_w C_L{}^2 + C_{L_T}{}^2\left(\frac{S_T}{S}\right)^2\left(\frac{1}{a_T}\frac{S}{S_T} + K_w - \frac{d\epsilon}{d\alpha}\frac{1}{a}\right) - C_{L_T}\frac{S_T}{S}\left(2K_w C_L - \frac{d\epsilon}{d\alpha}\frac{C_L}{a}\right) \qquad (10)$$

The pitching moment coefficient of the complete aircraft

$$C_M = C_{M_o} + (h-h_o)\,C_{L_w} - \frac{l_T}{\bar{c}}C_{L_T}\frac{S_T}{S}$$

and substituting for C_{L_w} from Eq. (9) and re-arranging gives

$$C_M = C_{M_o} + (h-h_o)\,C_L - \frac{l_o}{\bar{c}}\frac{S_T}{S}C_{L_T}$$

In trimmed flight $$C_{L_T}\frac{S_T}{S} = \frac{\bar{c}}{l_o}\left(C_{M_o} + (h-h_o)\,C_L\right) \equiv \frac{\bar{c}}{l_o}C_M$$

and if we substitute for $C_{L_T}\frac{S_T}{S}$ in Eq. (10) and re-arrange then

$$C_D = C_{D_o} + C_{D_{oT}}\frac{S_T}{S} + K_w C_L{}^2 + \left(\frac{\bar{c}}{l_o}\overline{C_M}\right)^2\left(\frac{1}{a_T}\frac{S}{S_T} + K_w - \frac{d\epsilon}{d\alpha}\frac{1}{a}\right) - \overline{C_M}\frac{\bar{c}}{l_o}\left(2K_w C_L - \frac{d\epsilon}{d\alpha}\frac{C_L}{a}\right) \qquad (11)$$

if $C_{M_o} = 0$ then

$$C_D = C_{D_o} + C_{D_{oT}}\frac{S_T}{S} + \left[X^2\left(\frac{1}{a_T}\frac{S}{S_T} + K_w - \frac{d\epsilon}{d\alpha}\frac{1}{a}\right) - X\left(2K_w - \frac{d\epsilon}{d\alpha}\frac{1}{a}\right) + K_w\right] C_L{}^2$$

where $X = (h-h_o)\,\frac{\bar{c}}{l_o}$

CONTINUOUS AIRWORTHINESS†

by K. E. Marsden*

Canadian Pacific Air Lines, Ltd.

INTRODUCTION

ANNUAL renewal of Certificates of Airworthiness within Canadian Pacific Air Lines was always a chore. The system was established whereby the personnel concerned with renewals of these Certificates were alerted one month prior to the expiry date for each aircraft. The required forms were then processed and forwarded to the Department of Transport. All of this amounted to a mountain of paper work, not only for the Company but also for the D.O.T. It was not unknown for the system to fail, with consequent embarrassing explanations.

C.P.A.L. learned that there was a possibility of obtaining a continuously valid Certificate of Airworthiness from the D.O.T. by a method similar to that practised by the C.A.A. of the United States. In order to qualify, the C.P.A.L. maintenance system would have to operate uniformly in both domestic and overseas operations.

Heretofore the domestic operation operated on a twenty-four hour sign-out system. Fortunately all aircraft on domestic operation return to a main base every twenty-four hours and this system, therefore, worked very well even if it was old fashioned. However, the overseas operation already met the continuous airworthiness requirement with minor exceptions.

After many arduous discussions among the experts in Vancouver, a draft was prepared of what appeared to be a practical system, meeting the D.O.T.'s requirements for both domestic and overseas operations. At the annual meeting of the Chief Mechanics from the 'out' stations, the new system was discussed and it is doubtful if any supersonic theory has ever been so completely shot to pieces by the practical people as was this plan. In the end, this discussion assisted appreciably in the development of our present system which has been operating very successfully for several months.

Now a Certificate of Airworthiness is good from the day it is issued for a new aircraft until the day that the aircraft is sold, provided that we abide by our D.O.T. approved continuous maintenance and inspection system.

†Received 19th July, 1956.

*Chief Inspector.

CHECKS

The following is a brief description of each Check.

Pre-Flight Check

The Pre-Flight Check includes checking of the pilot's report, a visual inspection of certain areas of the aircraft, checking of fuel, oil, other en route supplies and passenger-service items. The Pre-Flight Check is accomplished prior to all flights and also must be performed after a No. 3 (or higher) Check.

Aircraft Ground Test

This is a functional test of the powerplants and ancillary equipment and any other equipment that can be tested to advantage with the powerplants operating.

This Check is performed under the following circumstances:

(1) At the completion of a Pre-Flight where the layover exceeds eight hours.
(2) At the completion of a No. 1 or higher Check.
(3) At the completion of a powerplant change.
(4) When required to further investigate malfunctions.

No. 1 Check

The No. 1 Check includes the analysis of the flight crew's report and a general inspection of the outer surfaces, undercarriage, propellors, cabin interior, windows, doors, cockpit interior, cabin and cockpit equipment and supplies, and the checking of the batteries. The No. 1 Check procedure embraces all the items in a Pre-Flight Check.

This is the smallest Check that can be performed prior to signing an aircraft airworthy.

On scheduled operations, a No. 1 Check will be performed when the aircraft is to be on the ground at a main base for at least eight hours before scheduled departure.

The only argument offered in support of our choice of eight hours as a limit is that the normal work shift is of eight hours duration. With every shift change, there is an opportunity to forget to transmit vital information to people who may need it. No matter how short the period, up to eight hours, there is always the possibility of one shift change; if the interval is greater than eight hours, there will always be one shift change and possibly two.

On non-scheduled freight operations, a No. 1 Check is performed halfway between No. 2 Check periods.

No. 2 Check

The airframe section of the No. 2 Check is very similar to a No. 1 Check with the addition of a functional check of certain electrical items and the inspection and checking of specific known troublesome items. The No. 2 Check procedure embraces all the items in a No. 1 Check, including the Pre-Flight Check.

The powerplant section of the No. 2 Check calls for removal of engine cowling, inspection of sumps and screens, exhaust system and powerplant installation.

This Check is performed every 63 hours on domestic operations and every 150 hours on overseas operations.

No. 3 and higher Checks

These Checks are in five sections.

(1) Aircraft inspection (initial inspection by Inspection Department personnel).

(2) Aircraft Check (pre-planned work, flight crew complaints and additional work as revealed by initial inspection).

(3) Engine Check (pre-planned work, flight crew complaints and additional work as revealed by initial inspection. Engine initial inspection is performed by Maintenance Department personnel as an integral part of this Check).

(4) Electrical and Instrument Check.

(5) Radio Check.

The No. 3 Check is performed every 250 hours on domestic operations and every 300 hours on overseas operations.

MAINTENANCE RELEASE

A Maintenance Release is signed by an Air Engineer holding a current 'M' license suitably endorsed for the aircraft affected, under the following conditions:

(1) After Nos. 1, 2, 3, 4, 5 Checks and Overhaul.

(2) After powerplant change.

(3) Prior to test flight.

NO. 2 CHECK CYCLE

It may appear illogical to perform a No. 1 Check only when you have time (i.e., if you don't have the aircraft more than eight hours give it a Pre-Flight and send it on its way). This could result in an aircraft operating from one No. 2 Check to the next with nothing more than Pre-Flight Checks in between. However, if such were the case, it would mean that the hours were accumulated in a relatively short period of time and it is reasonable to assume that no more checking would be necessary.

Between No. 2 Checks, the most common items rendering an aircraft un-airworthy are:

(1) *Robbing parts not available in Stores*

This is a never-ending problem. When a part is robbed, we require an item to be written on an additional Work Sheet and a tag to be attached at the location from which the part was removed. As long as we have human beings, parts will be robbed without the required paper work being completed. Keep the aircraft in the air and this problem will not be encountered. An aircraft that is expected to be on the ground less than eight hours is not likely to be robbed. In all instances, we believe that the Pre-Flight Check will uncover items robbed during a period of eight hours on the ground and, when the aircraft has been grounded longer than this, the No. 1 Check and the aircraft ground test will point the finger at missing items.

(2) *In-flight difficulties*

These will be reported by the flight crew. Items affecting airworthiness will be corrected at the various stations en route. The rectification of airworthiness unserviceabilities will be entered and certified in the Flight Log Book. Such certification covers only the particular work done.

(3) *Damage by external objects*

(a) On the ground

(b) In the air

Where not reported, these will be uncovered by the Pre-Flight Check if they are at all serious.

(4) *Normal wear and tear*

The No. 2 and higher Checks are designed specifically to take care of normal wear and tear. These Checks undergo constant revision in order to fulfil this purpose.

CONCLUSIONS

This new system has reduced our routing problems as we no longer have to worry about exceeding the twenty-four hour sign-out period and aircraft can now be turned around in a minimum of time. No. 2 Check flying time is closely watched and provision is made ahead of time for proper accomplishment of this and higher Checks. Our very able Sales Department is selling more tickets and we, in Maintenance, are able to provide the extra flights with the same equipment and the same high, if not higher, standard of airworthiness.

Our next problem is to even the workload on No. 2 and higher Checks; we are working towards Equalized Checks with Progressive Overhaul.

Author's Note

It is not intended to imply that all of this is a brand new system. Should any reader notice areas in which he feels that some other company pioneered, he is no doubt correct and I would like to take this opportunity of thanking all who contributed to this system, whether they be individuals or groups, either inside or outside the employment of Canadian Pacific Air Lines.

TURBINE-POWERED AIRCRAFT FOR THE FUTURE†

by K. H. Larsson*

Canadair Limited

INTRODUCTION

THE matter of the new turbine era in air transportation is a subject that concerns us vitally these days.

We have, during the past few years at Canadair, followed the development of turbine engines and turbine-powered aircraft design closely and this paper is more or less a summary of conclusions we have reached in the course of this work.

The gas turbine, as we know it today, is a by-product of the last world war.

The idea of using turbines for aircraft came up at about the same time and independently in England (Whittle) and in Germany (Heinkel). As with all new ideas, it took some time to sink in, but as soon as it proved to be workable the development was accelerated as part of the war effort.

At the end of the war, England, therefore, had a substantial lead in the design and building of aircraft turbine engines and other countries, like the U.S.A., started by licensing British designs.

The Korean war then gave renewed impetus to turbine development in the U.S.A. and they were rapidly catching up with Britain, especially on straight jet engines. Canada developed a jet engine of her own — the Orenda.

In the U.K., however, work was carried on concurrently on both straight jet and two other variants, the propeller turbine and the so-called by-pass engine or ducted fan, with the result that England today has several successful turboprop engines and the only by-pass engine type in the world.

In the U.S.A., turboprop development has been largely neglected until recently, and no by-pass engine is currently being designed.

For the benefit of those who are not familiar with the three types of turbine engine, a brief description of their characteristics is given.

DESIGN CHARACTERISTICS OF THREE BASIC TYPES OF TURBINE ENGINE

Propeller Turbine (Turboprop, Figure 1)

The propeller turbine produces shaft power to drive a propeller through a gear and, in addition, some jet thrust by the exhaust gases escaping through the tail pipe.

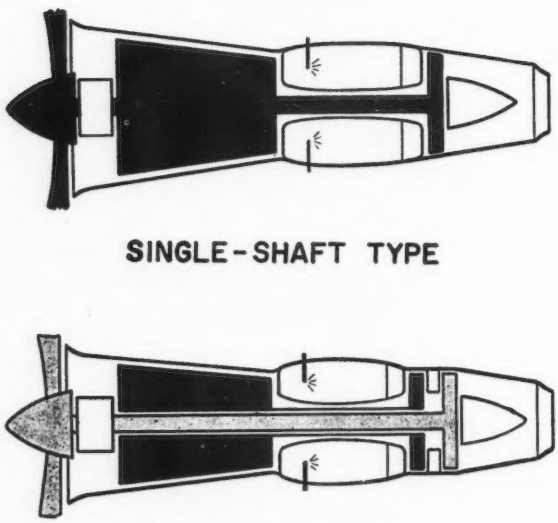


Figure 1
Turboprop

At takeoff about 80% goes to the propeller and 20% in the form of jet thrust, but this proportion varies, and when cruising at altitudes, almost all the power goes to the propeller.

This, as we shall see, accounts for the fundamental difference between the turboprop and the turbojet.

The basic equation reads:

$$\text{Force} \times \text{Speed} = \text{Power}$$
$$\text{lb} \times \text{ft/sec} = \text{ft lb/sec}$$

The unit for power being 1 hp = 550 ft lb/sec

Now, in the case of the turboprop which is essentially a "constant power" machine, this means that the product of force and speed are constant, i.e., when speed increases the force or thrust decreases and vice versa.

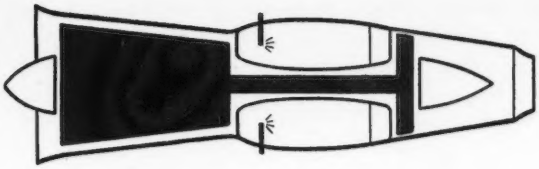
The turboprop, therefore, is essentially capable of high thrust at low speeds which, however, decreases as speed increases. This capability is further limited by the propeller, as we shall see in a moment.

Straight Jet Turbine (Turbojet, Figure 2)

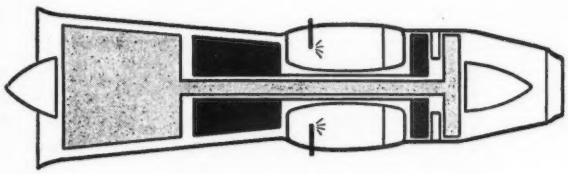
The straight jet turbine is a direct thrust producing machine. And let us immediately clarify the widespread misconception, even among engineers, that the thrust is caused by the exhaust gases pushing aside so much air

†Paper read at the S.A.E./C.A.I. meeting in Montreal on the 19th March 1956.

*Chief Sales Engineer.



SINGLE-SHAFT TURBINE



TWO-SPOOL TYPE

Figure 2
Turbojet

behind the engine: the thrust is explained by the law of action and reaction.

What is taking place inside the jet engine is nothing but a continuous or controlled explosion. This explosion accelerates the gases from a very moderate speed to something in the order of 1,500 fps, when they leave the tail pipe. To accelerate this mass of air requires a force, and the action of this force causes a reaction of the same magnitude, acting on the engine in the opposite direction, i.e., in the flight direction.

The jet engine in this respect can be compared to a big gun, in which the shell corresponds to the exhaust gases and the recoil effect is used for propulsion purposes.

The important difference between the straight jet and the propeller turbine is that the jet thrust is essentially independent of speed. In other words, as the jet aircraft picks up speed, the thrust from its engines is maintained and in fact even increased.

If we look once again at the formula

$$\text{Force} \times \text{Speed} = \text{Power}$$

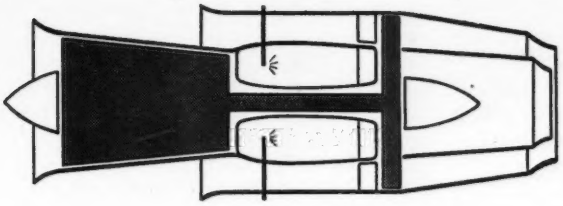
the force or thrust remains constant with increasing speed or, in other words, the thrust power available to propel the airplane through the air increases in direct proportion to the speed. This explains the high speeds attainable by a jet aircraft.

At the same time, however, we must appreciate that the jet exhaust, carrying all the effective thrust power due to its high relative speed, is inherently inefficient at lower flight speeds and terribly noisy during takeoff – just like the gun again!

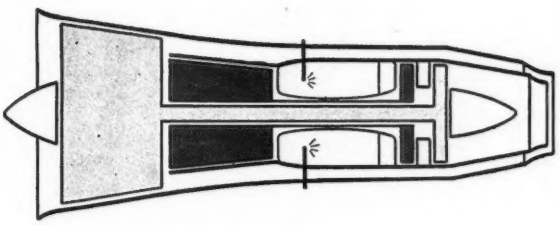
I have described these two extreme types of turbine engines first, because it makes it so much easier to deal with the third, the by-pass or ducted fan turbine, which technically falls in between the two and therefore combines certain of the characteristics of both – advantages as well as disadvantages.

By-Pass and Ducted Fan Engine (Turbofan, Figure 3)

We can visualize a by-pass or ducted fan engine as developed out of a propeller turbine, by letting the



DUCTED FAN TURBINE



BY-PASS TURBINE

Figure 3
Turbofan

propeller shrink in size until it can be housed inside the casing of the engine itself. In that case the propeller is likely to need more blades and it looks more like a fan – a ducted fan.

Some of the power is used to drive the fan which propels air through the engine in much the same way as the propeller. The remainder of the power is used as in the straight jet engine, to produce thrust.

In the by-pass variant the compressor is split in two, the front or low-pressure part furnishing air to both the annular by-pass and to the high-pressure compressor. The by-pass air stream joins the exhaust gases at the tail pipe end.

We find then that these types of engines are essentially thrust producing machines, however, with some limitations inherent in the ducted fan. The fan, being enclosed within a duct, operates in a flow of reduced velocity, thereby postponing the adverse effects of compressibility.

The most important advantage of the by-pass engine lies in the larger diameter jet pipe and consequently lower exhaust velocity, which together make the engine more efficient and less noisy than the straight jet.

The by-pass shroud around the engine is an advantage in that the outside temperature of the engine remains cool; on the other hand it makes the rest of the engine rather inaccessible.

From a performance standpoint, the by-pass engine falls somewhere between the propeller turbine and the straight jet. Where exactly depends on the by-pass ratio. If the ratio is high, it acts more like a turboprop, if it is low, it comes close to a jet engine in character.

A COMPARISON OF PROPULSION CHARACTERISTICS

Thrust characteristics of turboprop, turbojet and turbofan engines as a function of forward speed are shown in Figure 4. The turboprop is seen to give considerably more thrust for takeoff at low speeds, whereas

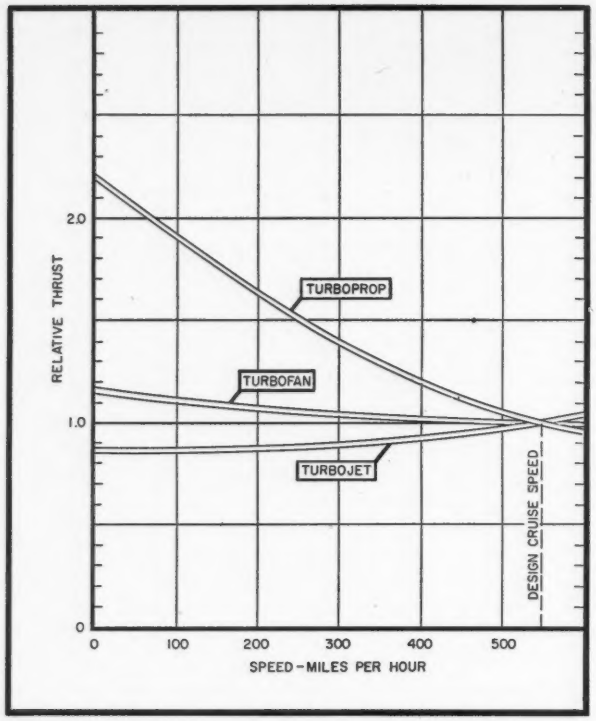


Figure 4
Thrust variation with speed

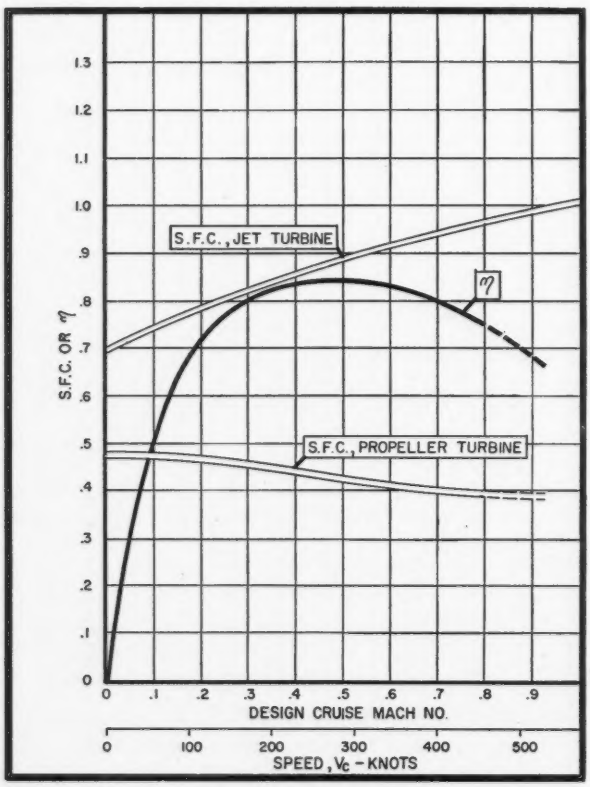


Figure 5
Engine and propeller characteristics

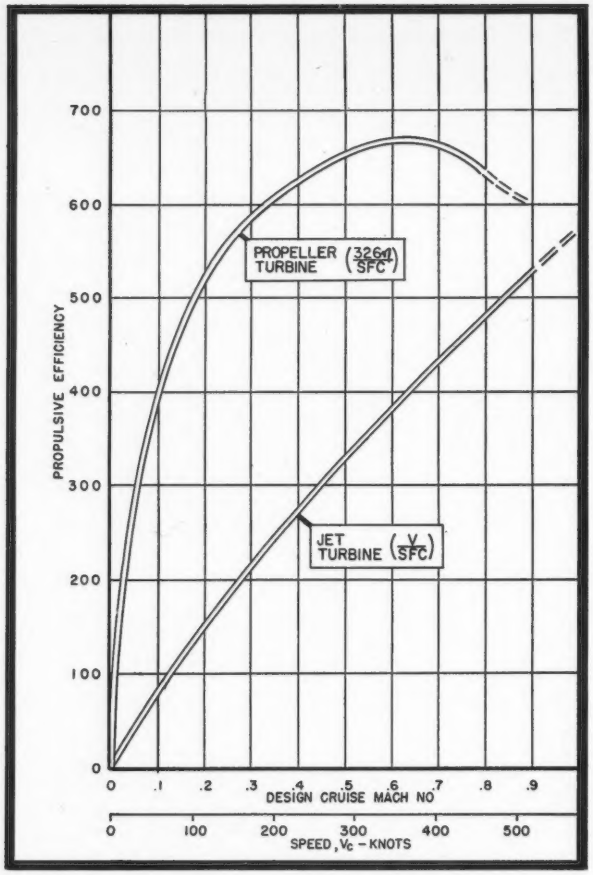


Figure 6
Propulsive efficiency

in flight at high speeds the turbojet provides more thrust. The turbofan represents a compromise.

Equally important, however, are the respective propulsive efficiencies or fuel economy, i.e., the specific fuel consumption in lb/lb of thrust at various speeds.

For a propeller turbine combination this efficiency is:

$$E_{TP} = \frac{326 \times \eta}{SFC}$$

where η = propeller efficiency,

SFC = specific fuel consumption, lb/ESHP/hour. For a turbojet engine forward speed takes the place of propeller efficiency as follows:–

$$E_{TJ} = \frac{V}{SFC}$$

where V = flight speed knots,

SFC = specific fuel consumption, lb/lb/hour.

Typical engine and propeller efficiencies for modern engines are shown in Figure 5 and an overall propulsive efficiency comparison in Figure 6.

This picture shows very clearly the great advantage of turboprop at low and moderate speeds, but also how the efficiency advantage rapidly deteriorates at speeds approaching $M = 0.8$ where the jet engine becomes more efficient.

The turbofan is more efficient than the jet at speeds in the region of $M = 0.65$ to 0.85 but, as already men-

tioned, when approaching the speed of sound, the fan suffers more of an efficiency loss than the compressor of a straight jet engine and limits the use of the turbofan or by-pass engine to subsonic speeds.

For supersonic speeds between Mach 1 and Mach 2, the straight turbojet is the only suitable powerplant and, for speeds higher than this, the ramjet comes into the picture.

DEVELOPMENT STATUS AND OPERATIONAL BACKGROUND

As already pointed out, the development of jet turbines has up till now been primarily a military concern, at least on this side of the Atlantic, which calls for high performance. Most of the money therefore has gone into development of the straight jet, of which there is now available quite a number in different sizes which are in large scale production and with an operational background that would make them suitable also for commercial purposes.

The largest of them have 14,000 to 16,000 lb thrust, good fuel economy obtained by split compressors and time between overhauls of 600 to 1,000 hours. Representative of such engines are, on the British side, the Rolls-Royce Avon and Bristol Olympus and, on the American side, Pratt and Whitney's JT3 and JT4. Another military engine which shows promise for civil use is the General Electric J79 of about 10,000 lb thrust. I have already mentioned the Canadian jet engine, the Orenda, of about 7,500 lb thrust rating which so far has only military application.

On the turboprop side, most of the designs are British, ranging in size from about 1,500 hp — the well-known Rolls-Royce Dart — up to 4,000 to 5,000 hp, of which the Rolls-Royce Tyne, Napier Eland and the Bristol Proteus and BE-25 are good examples.

Of these engines only the Dart has achieved an operational background in commercial use and a very successful one at that. The Proteus has also reached a fair number of flying hours and is going into scheduled operation in July this year. As for the rest of them, they exist only in small quantities, and it will be several years before they are available for commercial use.

In America there are two turboprops presently being flogged in military service tests. One of them, the Allison T56, is specified for the Electra; the other one is the Pratt and Whitney PT2 (T-34).

The only by-pass type engine in the world is the Rolls-Royce Conway, rated at about 16,000 lb thrust for takeoff. This engine is specified as an alternative to American jet engines in the new jet transports and offers interesting improvements in fuel economy and weight. However it exists only in very limited numbers and how to achieve enough operational background to be able to use it commercially by 1960 must be quite a problem.

TURBINE AIRCRAFT CHARACTERISTICS

Having discussed the various types of aircraft turbine engines and their characteristics, we shall now turn to a discussion of their suitability as powerplants for commercial transports of the future.

During the past years there has been a great deal of such discussion on the pros and cons of each one of the variants.

There have been statements by presidents of airlines and manufacturers favouring one type or the other; there have been numerous technical papers by engine and aircraft specialists; there have been conferences devoted solely to the discussion of these problems and there are excellent reports from various research organizations on the same subject.

It would be superfluous to try to give here another dissertation on such a highly technical matter and I shall try instead to summarize, as briefly as possible, the result of these studies and what conclusions, if any, we can draw from them.

In doing this, I shall avoid reference to any particular author or paper and shall instead make a general review with the aim of finding out in which respects they agree and what aspects are still a matter of controversy.

The most important characteristics of a commercial transport by which to judge the suitability of a type of engine are the following:

(a) Speed
(b) Economy
(c) Payload-Range
(d) Airport Needs
(e) Versatility
(f) Noise.

Safety is, of course, just as important as any of the above factors, but will be taken for granted once the aircraft has been certificated. As far as the engine itself is concerned, the safety factor can be considered to be taken care of by an adequate operational background of engine hours.

Speed

Everyone agrees that the jet engine is superior for speed by a margin of some 100 mph over the turboprop. The "natural" speed ranges for the three types of engines are approximately:

Turbojet	500-600 mph	optimum 550 mph
By-pass	450-550 mph	optimum 500 mph
Turboprop	400-500 mph	optimum 450 mph

By saying "natural" or optimum speeds, I mean those speed ranges which have been chosen by the aircraft designers after weighing carefully all pertinent factors, both economical and technical.

It should be pointed out though that, whereas the turboprop and by-pass engines are pretty much limited to the subsonic speed ranges mentioned (by propeller tip speed, noise, efficiency losses, etc.), the straight jet is capable of supersonic speeds of maybe Mach 2 — or about 1,300 mph — only limited by economic reasons.

Economy

There is a good rule in aircraft design — which may also be applied to many other fields — which says: the smallest and lightest vehicle for a given duty is the most efficient and also the most economical.

An examination of generalized studies of transport aircraft using the three variants of turbine power plants indicates the following relative numbers:

Turbojet Relative Gross Weight as	100%
By-pass Relative Gross Weight as	90%
Turboprop Relative Gross Weight as	75%

Some recent studies that we have made of a turboprop transport with North Atlantic non-stop range seem to bear out these relative figures:

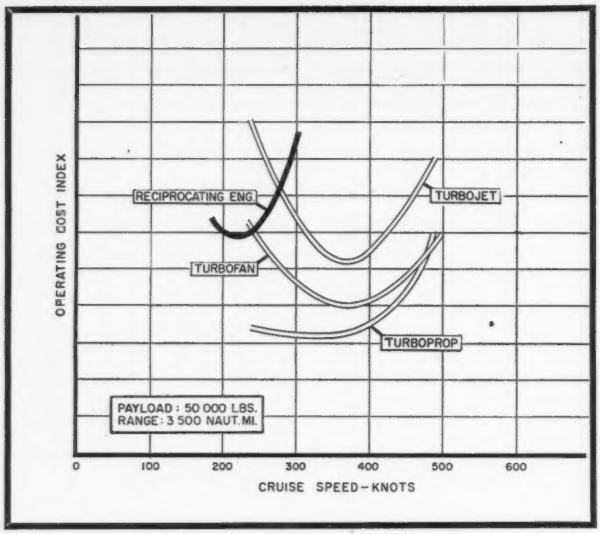


Figure 7
Operating cost comparison

Typical Turboprop Gross Weight	217,500 lb
Typical Turbojet Gross Weight	287,500 lb
Turboprop/Turbojet %	76%

Payload and range were about the same in both cases, the speeds 465 mph and 550 mph respectively.

Direct Operating Cost studies are always a controversial subject, especially when new aircraft with new types of powerplants are involved, of which there is very limited experience.

There are many unknown factors involved, for example, overhaul and repair cost of the turbine engines, time between overhauls, utilization of these high speed aircraft, etc.

However, we have run numerous cost studies using one or another of the standard cost formulae and the best I can say is that Direct Operating Cost per tonmile seems to follow very closely the gross weight trend:

Turboprop Direct Operating Cost	9.3c/tonmile
Turbojet Direct Operating Cost	12.5c/tonmile
Turboprop/Turbojet Cost	74%

Figure 7 shows a general comparison of relative cost for present reciprocating type engines compared with the three types of turbines.

Payload-Range

At one time it was a widely accepted opinion that jet aircraft could not be made to cross the North Atlantic westward with a reasonable payload and with adequate fuel reserves; such capability was, however, claimed for the turboprop.

The latest data published on the new Douglas and Boeing jet transports have refuted this assumption, but it is important to notice that this has been achieved largely by increasing the fuel load and gross weight. In other words, by reducing the payload in proportion to the fuel carried.

This brings up a fundamental point which cannot be too often repeated. The useful load of an aircraft is made up of payload and useable fuel (see Figure 8). It is possible within certain limits to exchange payload for fuel and vice versa to suit operational requirements.

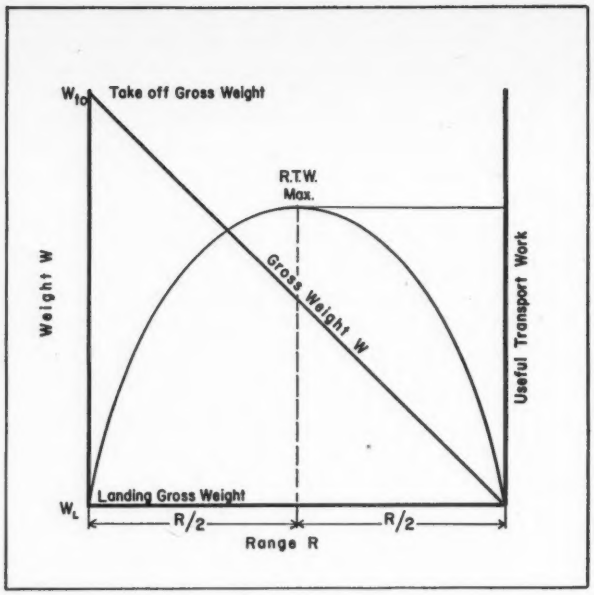


Figure 8
Payload-range

What is often overlooked though is the fundamental fact that an aircraft is most efficiently used when the useable load is divided about evenly between payload and fuel, because this is when the product of load (tons) and range (miles) reaches a maximum (tonmiles).

In the new jet transports projected, the payload has been reduced to about 26% of useful load and about 13% of takeoff gross weight. This compares with about 40% and 18% for a corresponding type of turboprop.

This is actually the very simple explanation of the long range capability of the jets and also of the better economics of the turboprop.

If both of them were designed to take 50/50 payload/fuel, the range of the jet would be shorter and the economics closer to those of the turboprop.

Because speed and long range are such strong selling factors, we find most of the present day airplanes and those planned for the near future compromised towards speed and range at the expense of operating cost.

Economy, of course, has two sides – the cost side and the revenue side, both equally important. The attractive characteristics of an airplane cannot be compromised too far in the interests of reducing cost. The revenue earning capability suffers and the net gain is turned into a loss.

Airport Needs

During the recent Jet Age Conference in Washington, the statement was made that there is only one airport in the U.S.A. with runways long enough to take the new jet transport and that is Hawaii Airport!

This may have been somewhat exaggerated, but there is no denying that the field lengths shown in these specifications have caused concern in many quarters and it has been suggested that only the main airports of the world can accommodate them.

What then are the actual field requirements? A real comparison can only be made on the basis of two aircraft taking the same payload the same distance.

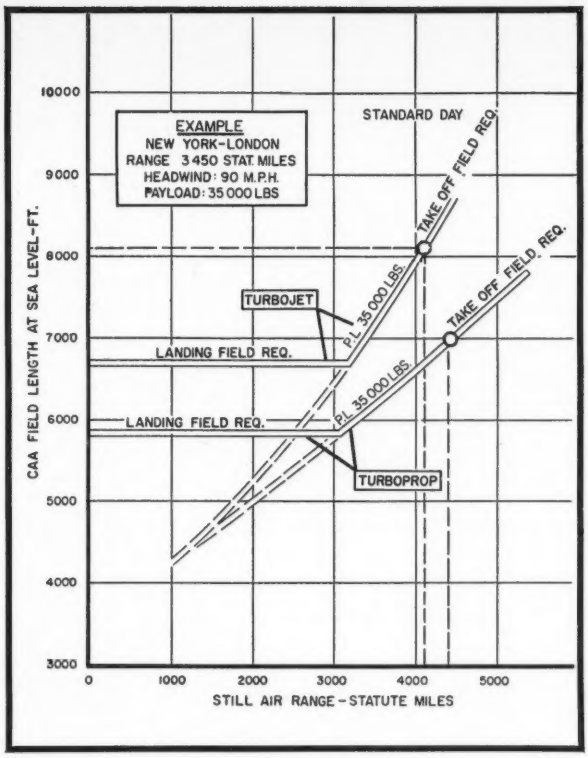


Figure 9
Field lengths required vs range

Figure 9 shows in graphical form such a comparison.

As an example, taking a payload of 35,000 lb to be carried London - New York (3,450 statute miles), against winter headwinds (90 mph) and with the usual fuel reserves, the field lengths required would compare as follows:

	Standard Day	Hot Day
Turboprop, full-power	4,700 ft	5,930 ft
derated	7,000 ft	7,500 ft
Turbojet, full-power	8,100 ft	9,700 ft
derated	9,550 ft	10,000 ft

Versatility

Any aircraft used over the route system of an airline has to meet varying operating conditions without too much penalty in performance or economy. This is closely connected with the so-called "off-design point" characteristics.

There is little doubt that the jet aircraft tolerates less deviation from design conditions than the turboprop and the latter, therefore, has the greater operational flexibility.

These characteristics are, for example, reflected in the amount of reserve fuel carried for a non-stop trans-Atlantic flight:

Turbojet, approximately 16,000 to 17,000 lb

Turboprop approximately 10,000 to 12,000 lb.

Also the turboprop is more flexible in the choice of operating altitudes, which is important when considering headwinds, one-engine-out performance, congestion of air space on high density routes etc. All together these factors give the turboprop greater versatility than the turbojet.

Noise

The noise problem, around airports, has been steadily increasing through the years and has now reached an acute stage.

It is generally conceded that the noise of jet engines during takeoff cannot be tolerated in the future and that jet airliners will have to have some noise suppressing arrangement.

Intense work in this direction is also going on. The results are promising, but even so the noise is going to be a nuisance around airports.

One of the most delightful surprises to aviation experts, I think, was the first public demonstration of the Bristol Britannia with turboprop engines at Farnborough a couple of years ago.

Since then, the Viscount has confirmed the first impression in daily operation and here is where the turboprop definitely scores one point over the jet.

In regard to noise inside the cabin, it is still too early to form a definite opinion. True, the Viscount has won strong approval from the travelling public, but with increasing engine power the noise in the propeller-plane will always present a problem of soundproofing.

On the jet, it depends somewhat on the engine arrangement. With pods out on the wing, the exhaust noise cone of the inboard engines hits the fuselage at the rear end of the cabin and is about as bad as the propellers.

With engines in the rear end of the fuselage — as on the French Caravelle — the internal noise is negligible, and this is probably the ideal arrangement from a passenger standpoint.

SUMMARY

In summarizing this discussion, I find that substantial agreement exists on purely technical matters which can be briefly summed up as follows:

(1) The jet engine is superior in speed while the turboprop is basically slower but more economical.
(2) For a given transport mission, the turboprop results in a smaller and lighter aircraft with more versatility and quieter operation.
(3) The by-pass or turbofan represents a cross-breed with characteristics somewhere between the turboprop and turbojet.

It is when we come to the interpretation of these characteristics and what they mean in practical life to the air carrier and the air traffic that opinions differ.

It is the weighing of such intangibles as speed, cost, noise, versatility, etc., that is difficult, as some of these factors mean more to one operator than to another and the aircraft manufacturer has to outguess both the travelling public's demands and how the airlines plan to meet them.

CONCLUSIONS

My conclusion is that each of the three engine types I have mentioned will, by virtue of their different characteristics, find their place in the future air transport picture. After all, specialization is a common trend in most other fields of endeavour.

I firmly believe that the turbojet transport, now in the design and construction stage, will take over all first class passenger traffic on the main routes during the 1960's. A large turboprop transport will be developed

for moderate subsonic speed and high load-carrying capacity that will take over tourist and coach passenger traffic, mixed cargo, and later, the growing air freight traffic.

By that time the turbojet might branch off into a supersonic type, eventually with ramjet augmentation, carrying the first class passengers and mail.

The other branch may be a by-pass or ducted fan, subsonic transport, which will take over second class passenger traffic, leaving third class, or the so-called B-class, to fill the large turboprop, carrying passengers and freight at minimum attainable fares.

Present piston engine aircraft will be gradually transferred from the world's main routes to secondary lines and later, after being written off the books, may be re-engined with suitable turboprop engines and live happily for another period of years in areas of the world which do not warrant the modern, larger size planes.

TECHNICAL FORUM

LETTERS TO THE SECRETARY

THE BIRTH AND EVOLUTION OF THE GAS TURBINE

I HAVE just read Mr. Crompton's notes on gas turbine history in the September 1956 issue of the Canadian Aeronautical Journal.

I think he has made errors and since mistakes in recording history, particularly when in responsible journals, tend to go a long way, I thought I should immediately write to you about it.

I refer only to Mr. Crompton's remarks about the German aspect of the history, as it seems to be rather distorted. It is surprising that he does not mention Heinkel's "Stürmisches Leben" in which he details his jet development. It was published in 1953.

Referring to Mr. Crompton's notes:

(1) 1930—German. I am sure that Prandtl never worked for Junkers.

(2) 1937—German. Heinkel says Ohain's engine ran first in Sept. 1937.

(3) 1939—German. Heinkel claims April 27 as date, not August.

(4) 1941—German. Heinkel says his He 280 twin flew April 5, 1941 with 2 He S-8 engines. It seems too early for either Me 262 or 003 engines. There was no Heinkel-Hirth engine. After Hirth's death, Heinkel bought the Hirth factory, in which was developed the He S-11. He makes no mention of any O11. The design of the S-11 was not that of the RLM, but used a type of blower they considered best.

Let us be clear; I am not saying everything that Heinkel writes is correct, but I do think that what he says should be taken into account.

London, England. B. S. SHENSTONE

AIR TRAFFIC CONTROL

Mr. McConachie's guest editorial in the September issue of the Journal dealing with Air Traffic Control has, I am sure, aroused a great deal of interest and not a little controversy. The statement of the case is, of course, correct; and the presentation displays a grasp of the problem that the reader has come to expect from a leader of world stature. However, there is an appearance of serene objectivity that may be a little disturbing to those responsible for bringing this phase of the dreams of the great world air operators to realization. Probably never since the Great Architect said, "Let there be light", has a problem of such staggering magnitude and baffling complexity been postulated with such Olympian detachment.

I have reference in particular to the last paragraph which states that it has already been established that jet aircraft can operate normally in piston patterns. They can, but the fact remains that operators who expect to use these craft by 1960 are now clamouring for the development of new techniques that will permit a maximum of utilization. It is, for example, pointed out that the present practice of "holding" and "laddering" do not permit of the fast turn-around so necessary for high utilization – the procedure that will permit a jet to make two trips to one of a piston job. And there are no illusions; the operators, rightly, will not be satisfied with anything less than full utilization.

This is one of the many headaches plaguing the toilers of the Air Traffic Control and, in their attempts to aid in bringing these mighty plans to fruition, they may be pardoned for thinking a little ruefully that one man's dream is another man's nightmare.

Ottawa J. R. K. MAIN

C.A.I. LOG

SECRETARY'S LETTER

NOVEMBER 1956 has been an eventful month. A new Branch has been established at Halifax, the formation of the first Section, the Test Pilots Section, has been approved, and the third International Meeting has taken place. Unfortunately, as all these things happened right at the end of the month, there is little that can be said about them in this issue of the Journal. A full report on the International Meeting will appear in January.

MATERIAL FOR THE JOURNAL

Material for the Journal is getting more plentiful than it was when we started but we still depend on the active interest and support of the members of the Institute to keep it going. It is the Institute's publication and, because every member has a stake in it, I should explain why we do some of the things we do and how our members can help.

From the material available, the Publications Committee tries to select four or five articles for each issue, covering a reasonable variety of subjects and producing a Journal of about the right size. Articles on similar subjects are not run in the same issue and whether there are four or five articles depends upon their length. That provides the basic framework but it often transpires that short one- or two-page articles could be fitted in without upsetting the general plan; in fact, a supply of such short items would be very helpful to us and would give us more flexibility.

I feel sure that many members who might never think of sitting down to write full-scale papers often write short reports and memoranda in the course of their daily work, which, with a little touching up, could be turned into short articles worthy of publication. Bear the point in mind. Incidentally, one side of an 8½″ × 11″ sheet, typewritten double-spaced, turns into about ⅓ of a page of print.

There is another point about the Institute's policy which is sometimes misunderstood. No purpose would be served by our publishing material which has been published elsewhere. Occasionally we may publish some particularly good paper simultaneously with another publication but only when the other publication is not generally available to our members. In any event, such simultaneous publication can only be done by agreement, because questions of copyright arise. It is commonly accepted practice that a paper presented at a meeting or printed in a publication of any technical or professional society becomes the property of that society, unless other stipulations are made, and naturally we must avoid treading on other people's toes, as they try to avoid treading on ours. But quite apart from toes and copyright, it is not our job to retell something which has already been told.

In this connection, however, we welcome abbreviated versions of reports and articles which in themselves would be too long for us to handle. Such items are most valuable in giving an outline of the work and referring, to the full report, those who are interested in studying the details. Dr. Wade's paper, published in our October issue, is a good example of this sort of thing and I would urge our members whose work entails the preparation of lengthy reports to remember this device for presenting their results to a wider public.

BRANCH MEETINGS

I sometimes wonder how many people read the reports of Branch meetings, submitted every month by the hard working Branch Secretaries and printed in the C.A.I. Log. Taken together, they are quite inspiring reading, for they reflect the month by month activity of the Institute. A very wide range of subjects is constantly under discussion and a goodly proportion of our membership is actively engaged; the attendances so far this year have been excellent. One is apt to form the impression that the Institute's annual programme consists of two or three two-day meetings, addressed by some thirty eminent speakers, and the publication of the Journal; it is well to realize that, besides all this, the Branches are staging about fifty technical meetings a year, many of them of a very high calibre.

HAPPY CHRISTMAS

The time has come again to send to all our members and friends best wishes for Christmas and for the New Year from C.A.I. Headquarters.

BRANCHES

NEW BRANCH

Halifax

At the meeting of the Council held on the 25th November, the formation of a Branch at Halifax, N.S., was approved. At present the Branch, which has rather more than 30 members, is administered by an Interim Committee comprising

Mr. E. C. Garrard, Chairman
CPO R. L. S. Sabourin, Vice-Chairman
Professor O. Cochkanoff, Secretary

There have been about a dozen members in Halifax for some time but recently interest has spread among the RCN personnel at HMCS Shearwater and the local membership has increased rapidly. Now that a Branch has been formed and as it develops a regular programme of activities, there is every prospect that it will grow and develop steadily as other Branches have done.

It is to be hoped that, with the formation of a Branch at Halifax, naval aviation will assume a more prominent place in the proceedings of the Institute. We look forward to publishing papers on some of the technical problems associated with naval aircraft and their operation.

POTENTIAL BRANCHES

There is every likelihood that the membership in and around Quebec City will soon exceed the minimum required for the formation of a Branch. The possibilities of a Quebec Branch have been under discussion for several months and applications for membership are being received in increasing numbers. Anyone interested should refer to

Mr. J. D. Dure,
2498 de la Falaise,
Sillery, P.Q.

Mr. Dure has kindly consented to act as "Interim Secretary"; he holds supplies of application forms and can give information on membership requirements etc.

NEWS

Cold Lake—Reported by R. W. Ellard

October Meeting

More than 30 members attended the meeting held in the library of the Sergeants' Mess on the 25th October. Mr. T. Clark, Supervisor of Industrial and Commercial Sales of Imperial Oil Ltd., from Edmonton and Mr. C. Pitcher, Chief Chemist for the Calgary Division of Imperial Oil Ltd., were the guest speakers.

S/L R. G. Christie, Chairman of the Branch, welcomed the newly admitted members of the Branch and then introduced the speakers. He thanked them for their persistence in getting to Cold Lake, despite the first snowstorm of the season, which had just occurred.

Mr. Clark showed films on the petroleum industry and then introduced Mr. Pitcher, who spoke on "Aviation Petroleum Products". He gave a brief history of the aviation petroleum industry in Alberta and proceeded to explain the various methods of refining and storing petroleum products.

Mr. D. L. Wallis thanked the speakers and a general discussion followed, in which both speakers participated.

Refreshments were served and the meeting ended at 11 p.m.

Winnipeg—Reported by D. C. Marshall

October Meeting

The October meeting of the Winnipeg Branch was addressed by F/L A. Morton, Flight Safety Officer for the RCAF Station, Winnipeg, on "Flight Safety". F/L Morton's talk, delivered informally on short notice, covered the RCAF approach to the problems associated with establishing and maintaining the best possible level of safety in all phases of aircraft operation. He added a plea that everyone connected with the industry be continuously on the alert for methods of improving the safety of aircraft operation.

F/L Morton stated that the RCAF has established a Directorate of Flight Safety, whose object it is to foster safety and efficiency in all phases of aircraft operations. This is achieved by continual monitoring of practices and equipment to discover unsafe conditions in any way connected with air or ground equipment, personnel, working conditions, initial and subsequent later training. It even covers social and recreational conditions of personnel.

In the RCAF approach, accident investigation is associated with flight safety but is a separate specialty. One job is to obtain data, to find causes and results. Another is to assess it, present and publish the significance and see that action is taken when indicated.

The impact of F/L Morton's talk on those present was very noticeable. During doughnuts and coffee after the meeting, several conversations were heard regarding the safety of various procedures and installations. It was the feeling of the meeting that one of the underlying purposes of design, maintenance and operational organizations is sometimes overlooked in the routine of day-to-day problems. Safety must, of necessity, be the major consideration in all aspects of aircraft and yet, too often, insufficient time is taken for an approach from considerations of safety for its own sake.

During the discussion period following F/L Morton's talk, it was mentioned that more and more organizations are establishing Flight Safety Departments. Co-operation among all organizations, civil and military, leaves room for improvement. One difficulty is reluctance to publish data which could have an adverse effect on the reputations involved.

The speaker was introduced by the Winnipeg Branch Chairman, Mr. J. J. Eden, and thanked by the Programme Chairman, Mr. B. W. Torell. The Winnipeg Branch was fortunate in obtaining F/L Morton on short notice when the original speaker was unable to attend.

Vancouver—Reported by I. A. Gray

Whirlybird Ball

The Whirlybird Ball, held in the Okanagan Helicopters' hangar on the 26th October, made a vertical take-off to the pinnacle of success. Some 250 members and guests attended and from all accounts everyone had a most enjoyable time; we look forward to a repeat performance next year.

The success was due to the efforts of the Programmes Committee, ably assisted by Okanagan Helicopters Ltd., and our special thanks go out to Gordon Askin, Jack Churchard and Harold Dow. The catering was done at cost by the flight kitchen of C.P.A.L. and the Chef, John Bergant, presided over the festive board, assisted by Mrs. Gray and Mrs. McWilliams.

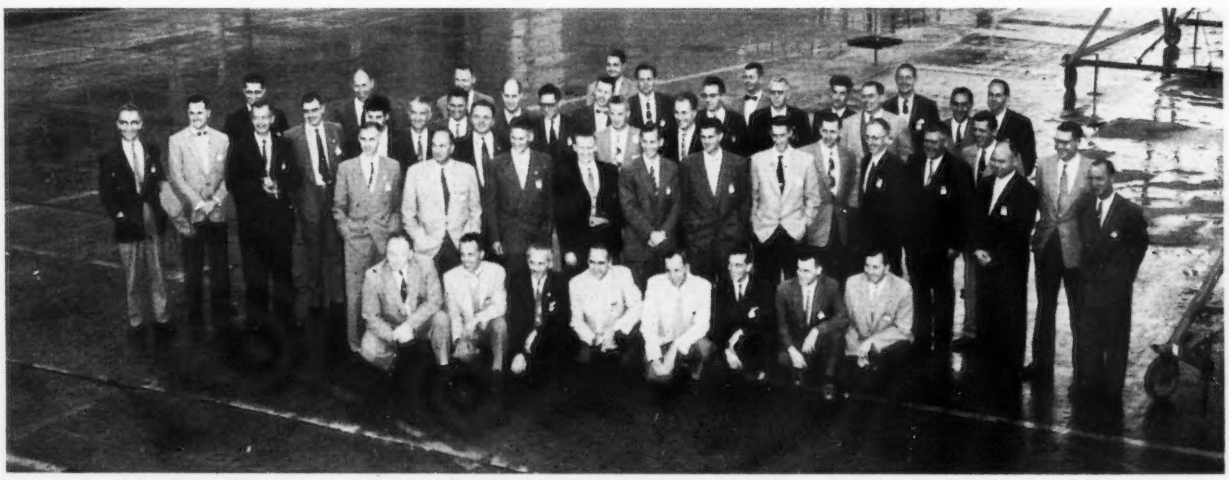
(*Several photographs were furnished by Mr. Gray but unfortunately only two are clear enough to reproduce satisfactorily. – Sec.*)

Vancouver Branch members at the Whirlybird Ball

October Meeting

Last month we printed Mr. Gray's report on the visit of the Vancouver Branch to the Boeing Airplane Co. at Seattle, on the 13th October. We have since received two photographs from Boeing, one of which is reproduced here. The inscription on the back of this photograph is of interest and reads as follows:

Canadian Aeronautical Institute members from Vancouver, forty strong, toured Boeing Airplane Co. with Seattle Section members of the Institute of Aeronautical Sciences guiding them through numerous plant facilities. They were photographed after a luncheon at which Maynard Pennell, Chief Engineer of the Transport Division, welcomed the visitors and described B.A.C. operations. It is hoped that this Vancouver-Seattle visit, a month before the CAI-IAS Toronto Conference, will extend into a series of pleasant exchanges and joint meetings in the future.



Vancouver Branch members at Seattle

MEMBERSHIP OF THE C.A.I.

as at the Meeting of the Council on the 25th November, 1956.

Technical	**1655**
Associates	**69**
Total	**1724**

The Technical grades comprise the following:

Honorary Fellows	11
Fellows	24
Associate Fellows	194
Members	839
Technical Members	454
Technicians	33
Students	100

MEMBERS

NEWS

A. H. Hall, A.F.C.A.I., has accepted an appointment to the Publications Committee to replace Mr. R. B. Ferris, who is unable to perform these duties due to his recent move to Montreal.

Dr. G. N. Adams, M.C.A.I., has returned from U.K. where he was working for Bristol Aircraft, to take up an appointment in the Engineering Dept. of Bristol Aircraft (Western) Ltd.

D. G. Allan, M.C.A.I., has left the Defence Research Board to take up a position as Project Engineer with the Transport Division of the Boeing Airplane Co. of Seattle.

G. G. Desloovere, M.C.A.I., has been transferred to the Research and Advanced Development Division of AVCO Manufacturing Co., Boston, as a Senior Staff Engineer.

R. B. Ferris, M.C.A.I., recently left A.I.T.A. to take up a post as Engineering Assistant to the Technical Director, International Air Transport Association.

LCDR(E) D. L. Foley, M.C.A.I., has recently returned from England and is now attached to Naval Headquarters in Ottawa.

J. H. Lacey, M.C.A.I., has left Canadian Westinghouse Co. to take up a position of Sales Engineer, Instrumentation Division, with the Applied Science Corp. of Princeton, N.J.

R. L. Trillo, M.C.A.I., who was formerly employed by Canadair Ltd., is now with the de Havilland Aircraft Co., Ltd., Airspeed Division, England, in the position of Senior Aerodynamicist.

J. B. O'Connell, Associate, formerly with Marconi, has been appointed Sales Supervisor of Samuel C. Hooker (Canada) Ltd.

F/C D. I. Shade, Technical Member, has been posted to the University of Alberta from his former position of Quality Control Inspector at Northwest Industries Ltd.

J. D. Koppernaes, Student, received an S.M. Degree from M.I.T. in September 1956 and is now employed by the Aluminum Co. of Canada as Maintenance Engineer in the Aluminum Fluoride plant.

OBITUARY

His many friends and colleagues throughout the aeronautical world will have learned with great regret of the untimely death of Donald Fraser, A.F.C.A.I. A graduate in Naval Architecture from Glasgow University, Mr. Fraser had a varied experience at the R.A.E. Farnborough, at A.&A.E.E. Boscombe Down and with the Air Registration Board before coming to Canada in 1946 to join the National Research Council. He was originally attached to the newly-formed Flight Research Section at Arnprior and contributed greatly to its early development as well as to its scientific activities.

In 1949, Mr. Fraser joined the N.R.C. Low Temperature Laboratory in Ottawa and assumed responsibility for the aircraft de-icing research. During this period, he undertook many hundreds of hours of test flying with the "Rockcliffe Ice Wagon" and made notable contributions in the fields of cloud physics and electro-thermal de-icing of aircraft. Latterly he was concerned with ice detection, automatic de-icing control systems and the application of electro-thermal de-icing of helicopters. As a result of this work, several patents were obtained and a number of his inventions are now being developed commercially.

Mr. Fraser was recognized as an outstanding expert in his field and he took an active part in various international meetings including those of the I.A.S., A.M.S., U.S.A.F., Mt. Washington and University of Michigan. He was the author of many important papers dealing with aircraft icing, one of which was presented to the 1953 Anglo-American Aeronautical Conference in London. In addition, he represented Canada on a number of specialist committees of the C.A.A.R.C. and A.G.A.R.D.

Donald Fraser brought to his work a practical engineering outlook combined with scientific thoroughness and a devotion to duty which was an example to his fellow-workers. His contributions to the safety of flying will long be remembered and his loss to aeronautical research in Canada will be keenly felt. In paying tribute to an esteemed colleague, our deepest sympathy is extended to his family and in particular to his son Donald who is a member of the C.A.I.

Ottawa — J. L. Orr

ADMISSIONS

At a meeting of the Council, held on the 25th November, 1956, the following were admitted to the grades of membership shown.

Associate Fellow

W. H. D. Hanchet (on transfer from Member)

Member

A. Allen, Drafting Supervisor, Orenda Engines Ltd., Malton, Ont.: *605 - 5th St., Port Credit, Ont.*

G. B. Asseltine, Field Service Engineer, Minneapolis-Honeywell Co., Toronto, Ont.: *General Delivery, MPO 503, Grande Centre, Alta.*

F/L A. M. Conley (on transfer from Technical Member)

W. Dunlop (on transfer from Technical Member)

E. L. Haines, Engineer, Canadair Ltd., Montreal, P.Q.: *490 Gohier St., Ville St. Laurent, Montreal, P.Q.*

I. J. Hammill, Assistant to the President, Walter Kidde & Co. of Canada, Ltd., Montreal, P.Q.: *Victoria Drive, Baie d'Urfe, P.Q.*

J. K. Hawkshaw, Chief Engineer, Field Aviation Co., Ltd., P.O. Box 366, Municipal Airport, Oshawa, Ont.

J. R. Holding, Design Draftsman, Canadair Ltd., Montreal, P.Q.: *181 Houle St., St. Eustache, P.Q.*

E. R. Keeping, Technical Service Representative, Canadair Ltd., Montreal, P.Q.: *11840 - 134 St., Edmonton, Alta.*

K. R. Knowlton, Sr. Electronics Engineer, Avro Aircraft Ltd., Malton, Ont.: *64 Scarborough Rd., Toronto 8, Ont.*

H. Kummen, Development Officer, Directorate of Vehicle Development, Ottawa, Ont.: *Box 162, Manotick, Ont.*

G. H. van Leeuwen, Project Planning Coordinator, Canadian Pratt & Whitney Aircraft Co., Ltd., Montreal, P.Q.: *4640 Clanranald Ave., Apt. 2, N.D.G., Montreal, P.Q.*

F/L J. B. Murray, Graduate Student, Institute of Aerophysics, University of Toronto, Toronto, Ont.: *101 - 24th Ave., S.E., Calgary, Alta.*

S/L E. S. Perkins, Officer Commanding 10 Repair Depot, Calgary, Alta.: *2608 38th St., S.W., Calgary, Alta.*

H. Stapleton, Supervisor, Instrument Laboratory, Northwest Industries Ltd., P.O. Box 517, Edmonton, Alta.

Technical Member

Cpl. A. E. Craig, Draftsman, CEPE/RCAF Climatic Detachment, Namao, Alta.: *11021 - 96th St., Edmonton, Alta.*

J. Godden, Inspector, Aero Engineering Ltd., Edmonton, Alta.: *10861-97th St., Edmonton, Alta.*

K. Grayson, Quality Control Technician, Trans-Canada Air Lines, Winnipeg, Man.: *128 Balfour Ave., Winnipeg, Man.*

S. Shapiro, Engineer, Canadair Ltd., Montreal, P.Q.: *5950 Cote des Neiges Rd., Apt. 16, Montreal 29, P.Q.*

H. W. Turatus, Instrument Technician, Northwest Industries Ltd., Edmonton, Alta.: *10043 - 116th St., Edmonton, Alta.*

Technician

D. Fraser (on transfer from Student)

E. Pitoulis, Sr. Draftsman, Northwest Industries Ltd., Edmonton, Alta.: *10643 - 125th St., Edmonton, Alta.*

Student

D. L. Allen, Student, Nova Scotia Technical College, Halifax, N.S.: *20 Parkwood Terrace, Halifax, N.S.*

G. C. Fabro, Student Engineer, Trans-Canada Air Lines, Winnipeg, Man.: *806 Dominion St., Winnipeg 10, Man.*

G. Kurylowich, Student, University of Toronto, Toronto, Ont.: *608 Pape Ave., Toronto, Ont.*

A. Sebe, Student, Sir George Williams College, Montreal, P.Q.: *6920 D'Otremont Ave., Apt. 3, Montreal, P.Q.*

R. O. Sochaski, Student, University of Saskatchewan, Saskatoon, Sask.: *1302 7th Ave. North, Saskatoon, Sask.*

R. Tremblay, Student, Laval University, Quebec, P.Q.: *30 Ave. Vimy, Quebec, P.Q.*

Associate

G. W. Northcott, General Manager, TransAir Ltd., Stevenson Field, Winnipeg, Man.

APPOINTMENT NOTICES

The facilities of the Journal are offered free of charge to members of the Institute wishing to give notice of positions vacant or required. Notices will be published for two consecutive months and will thereafter be discontinued, unless their reinstatement is specifically requested. A Box No., to which enquiries may be addressed (c/o The Secretary), will be assigned to each notice submitted by an individual.

The Institute reserves the right to decline any notice considered unsuitable for this service or temporarily to withhold publication if circumstances so demand.

Box 100 **Aeronautical Engineer** B.Ae.E. Thirteen years experience, covering design, flight test and analysis of aircraft and helicopters, industrial engineering, sales engineering, with four leading Canadian manufacturers and airlines, desires improved opportunities as Technical Assistant to Management, Technical Sales Representative or Planning and Economic Analysis.

Box 101 **Aeronautical Engineer** Twelve years experience in research, design, flight testing of aircraft, missiles and power plants, systems engineering, seeks position with industry or airline. Ample experience in contract and project administration on staff level and liaison engineering.

SECTIONS

TEST PILOTS SECTION

UNDER the heading SECTIONS in the last issue of the Journal (page 341), details were given of a new plan, devised to give improved service to specialist members of the Institute. The plan, in outline, had been discussed in the early days of the Institute – rather as an abstract idea than as a serious proposal – but it was given fresh impetus by the tentative formation of the Canadian Test Pilots Society last spring. The test pilots were invited to consider the reformation of their Society as a Section of the C.A.I.

Details of the plan were worked out by the Specialist Services Committee, approved by the Council and then submitted to the Board of Directors of the C.T.P.S. for study. The proposal was accepted and, as a result, the formation of a Test Pilots Section of the Institute was approved by the Council on the 25th November, 1956.

Interim Committee

Pending the formal election of Officers, the Interim Committee of the Section is

Mr. W. S. Longhurst, Chairman
Mr. D. H. Rogers, Vice-Chairman
F/L J. C. Henry, Secretary-Treasurer

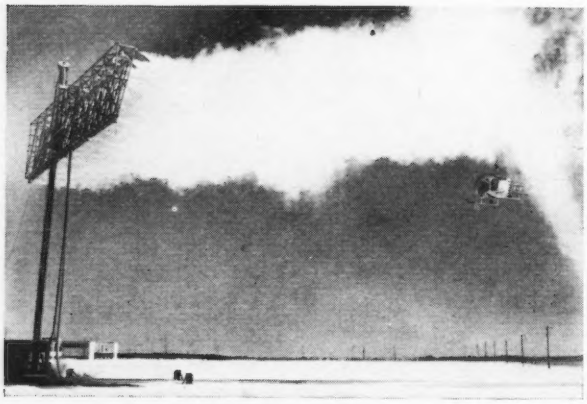
Membership

The "Identifying Qualification" for membership of the Section reads as follows:

"All members of the Institute who are or have been engaged as pilots in experimental, development, production or maintenance flight testing shall be eligible for membership of this Section."

There is a special form of application for admission to the Section; copies can be obtained from the Secretary of the Institute. Any member of the Institute who believes that he possesses the Identifying Qualification, quoted above, and who wishes to belong to the Section should complete one of these forms and submit it to the Secretary. Anyone who is not yet a member of the Institute but who wishes to join the Section, may submit simultaneously an application for membership of the Institute and an application for admission to the Section; acceptance of the latter cannot, of course, become effective until the applicant has been admitted to full membership.

SUSTAINING MEMBERS



N.R.C. Spray Rig

NEWS

The Bristol Aeroplane Company of Canada Ltd. has announced that a Sycamore helicopter is shortly to be shipped to Canada for a series of extensive tests on rotor blade de-icing equipment. In the tests, which will be carried out at the N.A.E., Ottawa, icing conditions will be simulated by stationing the helicopter at heights from 50 to about 70 ft in a cloud of steam blown through the nozzles of an especially designed low temperature spray rig, installed at the top of a tall mast. As the steam condenses on the rotor blades it becomes frozen and an ice film is gradually built up. (This rig shown above was described in the Canadian Aeronautical Journal in May 1955.)

For test purposes, the Sycamore has been fitted with a cyclic electrical power system which operates a series of thermal-electric mats, extending along the leading edge of the outer two-thirds of the main rotor blades. Fabricated in moulded rubber sheeting and covered by a stainless steel anti-corrosion sheath, the mats are provided with eight metal elements which are heated successively by means of an electric current controlled by a cyclic switch mounted on the rotor hub. Power required for the operation of the de-icing equipment will be provided by a ground alternator connected to the Sycamore by a trailing lead. By this method it will be possible to assess the power rating needed to meet various icing conditions and obtain the necessary data for the design of a special airborne alternator.

The tests are to be carried out in order to evaluate under actual flying conditions the performance of the Goodyear rotor blade de-icing equipment which is under consideration for the Bristol Type 192 twin-engined, tandem rotor helicopter.

Okanagan Helicopters Ltd. recently took delivery of its first Sikorsky S-58B helicopter. The aircraft was flown from Bridgeport to Great Slave Lake, a distance of over 2,800 miles to augment the Company's fleet working on defence installations. The accompanying picture shows the Company's Chief Pilot, Mr. Fred Snell, waving goodbye to Mr. Igor Sikorsky, Engineering Manager of the Sikorsky Aircraft Division, United Aircraft Corporation.

Okanagan's Sikorsky S-58B

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MEMBERSHIP OF THE C.A.I.

THE qualifications and annual dues set out in the table below are those presently laid down by the By-laws. The rates of dues shown in brackets are those applicable to members who are also members of the R.Ae.S., I.A.S. or E.I.C. or who are resident outside Canada or the U.S.A.

The annual dues include a non-deductible subscription to the *Canadian Aeronautical Journal.*

Applications for membership must be made on the approved forms, which may be procured from the Secretaries of the Branches or from C.A.I. Headquarters. An applicant does not apply for membership in any particular grade, but each application is considered by the Admissions Committee and by the Council, who decide the grade suitable to the applicant's qualifications. On admission, the applicant is informed of his grading and the appropriate entrance fee and annual dues.

The entrance fee is $5.00, except in certain special circumstances.

GRADE	QUALIFICATIONS	ANNUAL DUES
Student	Undergoing a course of study at an approved school of engineering or technology	$3.00 ($2.00)
Technician	Engaged in technical work in aviation	$5.00 ($2.00)
Technical Member	Engaged in science, engineering, research, manufacture or operation, in aeronautics or related fields, for 4 years or graduated from an approved school of engineering or science	$7.00 ($4.00)
Member	Engaged in aviation for 8 years and acquired a recognized standing	$8.00 ($4.00)
Associate	Engaged in aviation, though not qualified for technical grades	$8.00 ($4.00)
Associate Fellow	Engaged in aeronautical science or engineering for 10 years and been in responsible charge or made outstanding contribution	$9.00 ($5.00)
Fellow	Been an Associate Fellow for 1 year and attained distinction in aeronautics	$10.00 ($5.00)

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   (b) PROJECT ENGINEER (ELECTRONICS) — Requirements are a degree or British Higher National Certificate in Electrical Engineering and a minimum of five years subsequent experience in the design of aircraft electrical and electronic installations and the organization of ground and flight tests.

   (c) PROJECT ENGINEER (COMMERCIAL AIRCRAFT INSTALLATIONS) — Requirements are a British Ordinary National Certificate in Mechanical Engineering, or equivalent qualification, and at least ten years experience of the design of installations, preferably in commercial aircraft.

   (d) TECHNICAL EDITOR (PUBLICATIONS) — Requirements are a British Higher National Certificate in Mechanical Engineering or equivalent qualification and at least ten years experience of the preparation and production of aircraft technical publications to R.C.A.F. or British M.O.S. standards.

   (e) TECHNICAL AUTHORS, and

   (f) TECHNICAL ILLUSTRATORS — Requirements are a minimum of three years experience of writing or parts listing, or illustrating aircraft technical publications to R.C.A.F. or British M.O.S. standards.

   (g) SENIOR CHECKER — Requirements are about fifteen years drawing office experience on aircraft work and ability to lay out and check installations and details. British Ordinary or Higher National Certificate would be an advantage.

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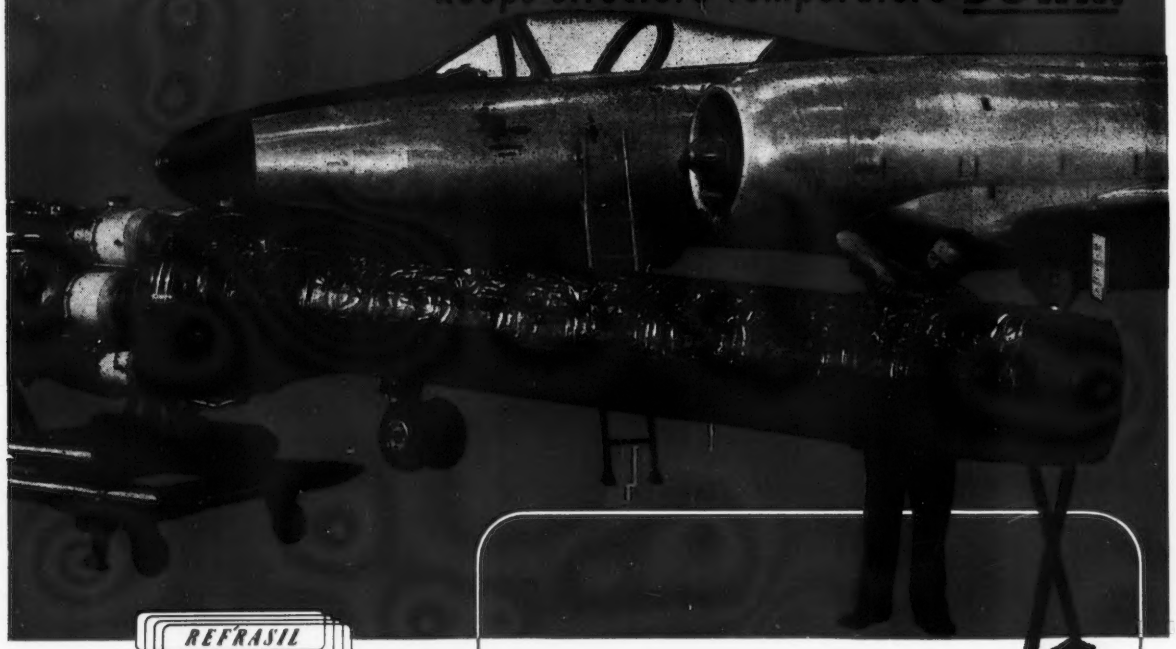

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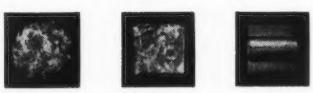

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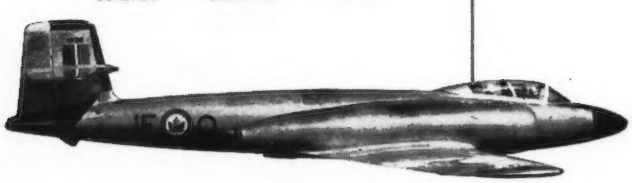

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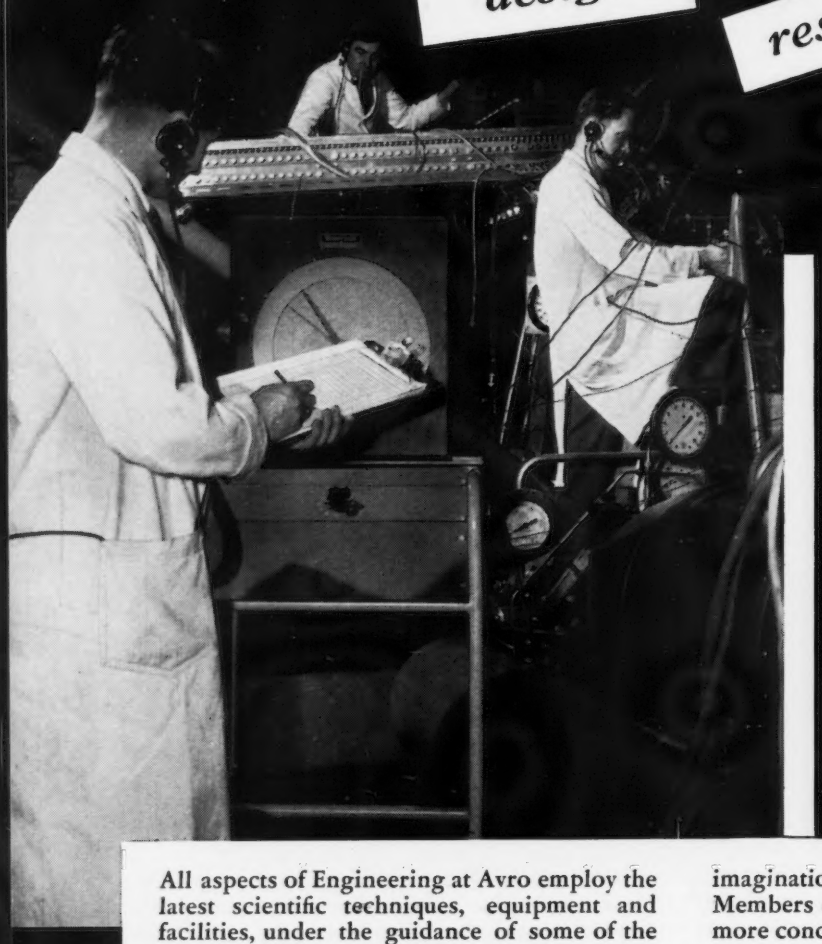

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